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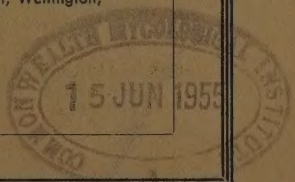

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NEW ZEALAND

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VOLUME 36, No. 6, 1955

(AGRICULTURAL RESEARCH SECTION)

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NOTICES

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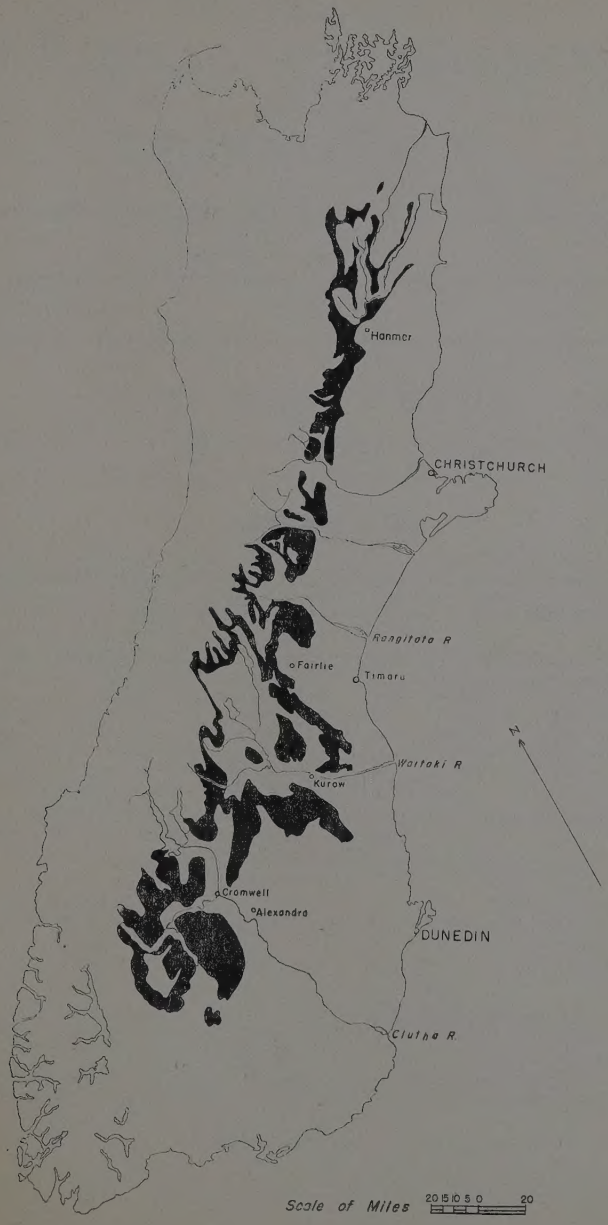

Fig. 3.—Distribution of snow-tussock grassland in South Island, New Zealand. (Prepared by J. D. Raeside.) Note—Section north of Hanmer corrected since publication.

CORRIGENDUM

This amended map replaces the map on page 338, Volume 36, A (December 1954).

The alterations are mainly in the area north of Hanmer, with a slight change east of Kurow.

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SPOTTED COLOUR IN BUTTER

By R. M. DOLBY, The Dairy Research Institute (N.Z.), Palmerston North

(Received for publication, 8 December 1954)

Summary

Samples representing the principal brands of dairy salt in use in New Zealand were examined. Two samples were of salt to which spotted colour in butter had been attributed. Variations between samples in crystal size and rate of solution were found to be small and were considered unlikely to be significant in buttermaking.

The most important factor was the quantity of water available for dissolving the salt. It was concluded that water enclosed as fine droplets within the granules ("internal" water) is not available during the time the butter is in the churn. Although the total water content ("internal" and "external") of the butter when the salt is added is usually about 15%, some two-thirds of this water is held within the granules. Where the free ("external") water is insufficient to dissolve all the salt, spotted colour will develop in the butter.

The factors that increase the moisture within the granules and hence cause an increased tendency to spotted colour are:

Vacreator treatment of cream (as compared with flash pasteurization) especially at high intensity.

Dilution of cream.

Slow cooling of cream or cooling of cream in stages to churning temperature.

High churning temperature.

Churning to large granules.

A seasonal variation in moisture content of granules churned under standard conditions was observed. It was attributed to changes in composition or dispersion of butterfat.

Salt milled to 100–200 mesh could be used safely under conditions where salt of normal particle size caused development of spotted colour.

INTRODUCTION

Spotted colour is a defect of butter characterized by the presence of numerous dark-yellow spots throughout the sample. It may be considered a particular form of the colour irregularity known as mottling. Butter with mottled colour has deep-yellow blotches interspersed with paler yellow or whitish areas. While the dark patches in mottled butter may be of any size and the colour within the patches is uneven, the spots in spotted butter seldom exceed 2 or 3 mm in diameter and the butter

between the spots is usually uniform in colour. Examples of mottled colour are shown in Figs. 1 and 2 respectively.

It was shown by Hunziker and Hosman[1] in 1920 that mottles appeared only in salted butter that had been incompletely or unevenly worked. They demonstrated that the colour of butter depended on the size of the water droplets—large numbers of minute droplets caused

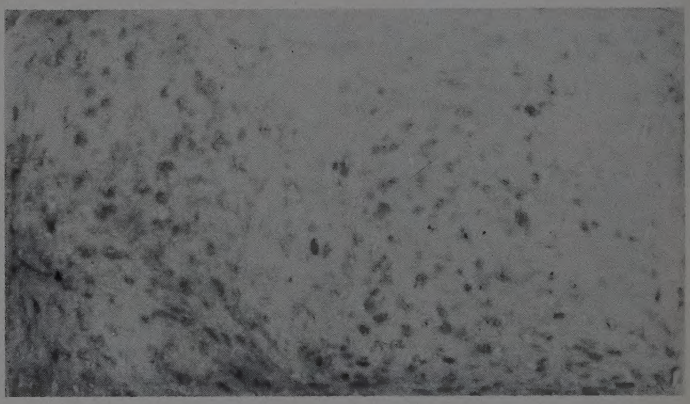

Fig. 1.—Section of 1lb. pat showing mottled colour.

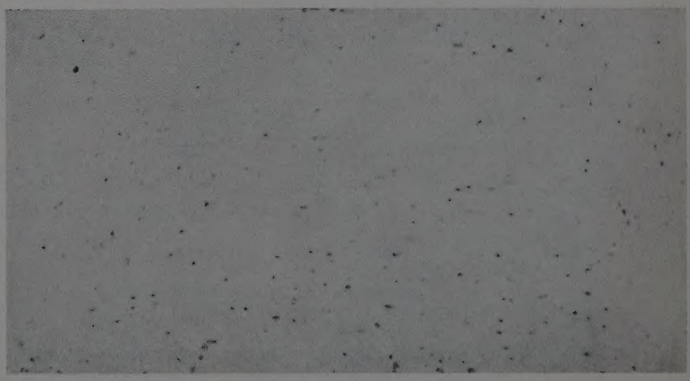

Fig. 2.—Section of 1 lb. pat showing spotted colour.

(Butter samples in Figs. 1 and 2 were photographed on Microfile film through blue filter—Wratten H).

the butter to be opaque and light-coloured, fewer and larger droplets made the colour a deeper and clearer yellow. Diffusion of water to areas of high salt concentration resulted in a reduction in number and an increase in size of the droplets so that these areas took on a deeper yellow colour.

Muller[2] in 1949 confirmed these conclusions and showed that in extreme cases of mottling some of the large water droplets in the dark-yellow patches contained undissolved salt crystals.

The above work has referred particularly to mottled colour. Spotted colour has also been attributed to the action of salt, i.e., to the presence of undissolved salt crystals in the butter when it leaves the churn. Each of these crystals by attracting water from the butter near to it will cause the appearance of a dark yellow spot, the ultimate size of which will depend on the size of the salt crystal.

While mottles may be prevented by adequate working of the butter, spotted colour may occur even where the butter has been well worked.

Various conditions in buttermaking that may lead to development of spotted colour have been given by McDowall[3]:

1. Salt grains too large (although most uncaked butter salts are sufficiently fine for normal salting conditions).
2. Carelessness in adding salt to churn. Salt crystals may lodge in places in the churn with which the butter does not come in contact but from which they may fall into the butter during the later stages of working.
3. Allowing insufficient time of contact between salt and granules before commencement of working.
4. Churning to too large a granule before salting.
5. Churning to too low a moisture before salting, with the result that there is not enough free water to wet and dissolve the salt.
6. Churning at too low a temperature, which may result in too slow diffusion of water to the salt crystals.
7. Churning at too high a temperature so that (a) salt crystals are surrounded with liquid fat before they are dissolved, and (b) butter works up too quickly, i.e. before salt is dissolved.
8. Butterfat of high melting point is specially likely to give spotted colour.

Although mottled colour is not a common defect in New Zealand butter, spotted colour appears from time to time despite the fact that there is already available much information on the origin of this defect. In some instances, spotted colour may be due to lack of care in manufacture and to neglect of established principles, but in others the cause is not obvious. For example, the butter from a particular factory may for some months be consistently free from colour defects and then, over a further period, although there has been no change in technique, a proportion of the churnings are found to have spotted colour. This occurrence of spotted colour may continue intermittently for some time and then cease completely. A number of factories may be affected at the same time. The adoption of special precautions sometimes reduces the number of churnings showing spotted colour but in other cases the defect continues to appear despite all efforts made to eliminate it.

It would seem that the requirements for obtaining complete solution of salt in butter are not fully understood and that a further investigation of the problem is justified.

The papers quoted above do not make it clear whether it is necessary that the salt be completely dissolved before working of the butter is commenced or whether solution of salt can continue during the working process. In either case further working would be required after the last of the salt has dissolved in order to effect a uniform distribution of the brine formed.

It was shown by Boysen[4] from miscroscopic observations that diffusion of water to a salt crystal in butter is comparatively slow. In 1 to 2 hours only a small amount of water had collected around the crystal. More than 6 hours had elapsed before the volume of the water approached that of the crystal. Even after 10 hours the crystal had been only slightly reduced in size by dissolution.

This period of time required for diffusion is consistent with the interval before the appearance of mottled colour in butter—according to Hunziker and Hosman[1] mottles develop 6 to 12 hours after churning.

It is evident from the above that when salt crystals have been worked into butter only an insignificant amount of water can reach them by diffusion during the time the working process continues. The crystals may be brought into contact with drops of water by the action of working the butter, but the opportunities of contact beween salt crystals and water during working will be much more restricted than when the butter is still in granule form.

Before working is commenced, part of the water is in a free state, either on the walls of the churn or adhering to the surface of the granules. The remainder is in the form of small droplets within the granules. Mulder[5] has referred to these two forms of moisture in butter as *external moisture* and *internal moisture,* respectively. He points out that small butter granules having a larger total surface will retain more external moisture than large granules. With harder fat, the canals between granules remain open and drainage is facilitated. Mulder has suggested that one of the main factors influencing the amount of internal moisture is the hardness of the fat globules. If the globules are harder, they retain their spherical shape and more space is available for water in the interstices. The content of entrapped moisture is therefore higher. Apart from interstices between globules, larger cavities containing aqueous phase may be present. These cavities are found more frequently in the larger granules.

According to Mulder, the distribution of internal moisture is almost unaltered during working, but as the external moisture is incorporated in the butter the large drops are gradually subdivided.

If the salt must be brought almost completely into solution while the butter is still in the granule form, the water available for dissolving it is limited to the external water. The internal water, being in the form of fine droplets enclosed within the granules, cannot diffuse out in the short period allowed. The amount of water available for dissolving the salt is therefore very much less than would appear at first sight to be present.

The total amount of moisture in the churn at the stage when the salt is added cannot be determined directly, but it may be found a little later when all external moisture has been worked into the butter. It is

at this stage that the "first moisture test" is made by the buttermaker. Provided that no water is added or withdrawn between the times of adding the salt and making the test, the result of the test will show the total moisture content at salting.

It is known that there is a risk of colour defects if the butter is churned to too low a total moisture content (McDowall[3]) but there is evidently an equal risk if the internal moisture in the granules is too high.

An indication of the internal moisture content of washed butter may be derived from its buttermilk content, which can be estimated from the concentrations of lactose present in butter and buttermilk. Using this method, Mulder[6] obtained values of 7.6% and 8.5% for buttermilk content of butter from 25% cream, and 10.7% and 13.0% for butter from 9% cream. By a similar method, McDowall and McDowell[7] found values ranging from 7.9% to 11.5% (av. 9.4%) for buttermilk content of 26 churnings of New Zealand commercial butter.

A direct determination of the internal moisture in butter granules may be made if the granules are first completely freed from adhering water. Farr[8] in 1922 found that dry butter granules contained 11% of moisture.

From the above data it would appear that the internal moisture in the granules is of the order of 10%. The total moisture in butter at the salting stage is usually kept to about 15%. (The extent of draining of the churn required is a matter of judgement and some safety margin must be allowed by the buttermaker as a means of reducing the risk of producing overmoist butter, i.e., butter containing more than the legal maximum of 16% of moisture). The free or external water is therefore of the order of 5%. This is very little in excess of the amount required to dissolve the salt added. (1.5 parts of salt would require a minimum of 4.2 parts of water.) If either the internal moisture is high or the total moisture is low, some of the salt may remain undissolved.

The effect of variation in total and internal moisture contents has been investigated in the experiments to be described. A study has also been made of the particle size and rate of solution of commercial butter salts, of different techniques of salting, and of some other conditions likely to affect the incidence of spotted colour.

Examination of Samples of Commercial Dairy Salt

Samples of four brands of salt referred to as A, B, C, and D were received from dairy factories. These samples represented the principal brands of dairy salt in use in New Zealand. Spotted colour in the butter from two factories had been attributed to use of salt C. In one of these factories the colour defects disappeared when a change was made to salt A. A third factory, however, had used salt C without experiencing colour defects in the butter. In another factory, spotted colour occurred when salt B was in use and disappeared when a change was made to salt D1. Sample D2 was of the same brand as D1 but was obtained from a different factory.

It was learned later that brands A and B were made by the same firm and were essentially the same salt sold under different brands.

Microscopic Examination

Photomicrographs of the various samples are shown in Fig. 3. A sample of fine milled salt (F) is included for comparison. All the samples A–D had cubic crystals typical of vacuum salt. Sample A contained the coarsest crystals and sample D the finest.

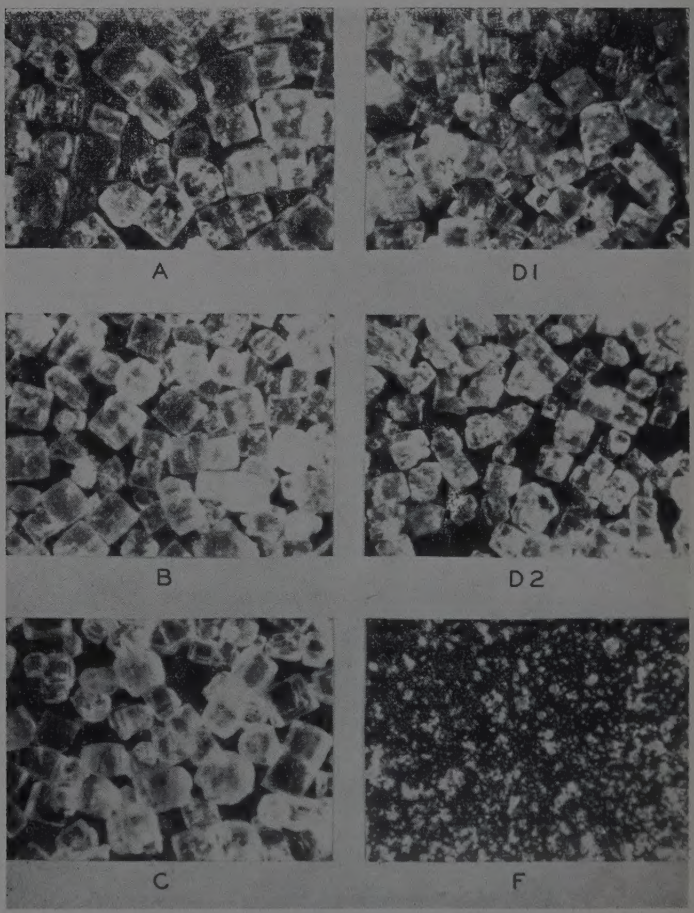

Fig. 3.—Photomicrographs of salt crystals, × 50.

Sieve Analysis

A portion of each sample was oven-dried. Any lumps were broken up and the sample was passed completely through an 18-mesh sieve. Fifty grammes of each were weighed out and sieved in a series of B.S. sieves. Results are given in Table 1.

TABLE 1. SIEVE ANALYSIS OF SALT SAMPLES

Mesh range	A	B	C	D1	D2
18–25	4.95	0.95	0.3	0.2	0.4
25–30	7.35	2.25	1.6	0.75	0.85
30–36	19.0	15.4	9.6	4.15	2.85
36–44	22.85	20.15	28.7	10.75	5.0
44–60	39.8	44.8	54.9	54.75	46.45
60–	5.75	15.85	4.9	29.05	43.95
Loss	0.30	0.60	0	0.35	0.5
	100.00	100.00	100.00	100.00	100.00

The sieve analysis agreed with the miscroscopic examination in showing that sample A was rather coarser than sample D. It was found, however, that the particles retained on the coarsest sieve were not single crystals but were aggregates of crystals as shown in Fig. 4, so that their rate of solution would be greater than indicated by the mesh size.

Fig. 4.—Salt crystals retained on 25-mesh sieve.

Rate of Solution

Hunziker[9] measured the rate of solution of salt by adding a weighed quantity of salt to water which was mechanically stirred. Samples were withdrawn at intervals by means of a pipette with a filter attached to the tip. Determinations of salt concentration were made on the samples and a graph of concentration against time was plotted.

It was desired in the present investigation to use a method which would indicate the time required for the largest and hence the most slowly dissolving crystals to pass into solution. In preliminary trials

it was found possible to obtain an approximate idea of the rate of solution by adding 20 g. of salt to 100 ml. of water in a measuring cylinder, shaking for a definite number of seconds and then, after allowing the solution to stand, examining for presence of any undissolved crystals at the bottom of the cyclinder. After a few repetitions it was possible to find the minimum time required to dissolve the salt completely.

Later a more convenient method was developed permitting continuous observation of the dissolving process. It was found that crystals of salt suspended in the solution were readily visible if the solution was illuminated from one side. Bubbles of air introduced with the salt interfered with the observations but could be removed by a brief application of a vacuum to the solution.

The determination was conducted as follows: a cylindrical glass jar (12.5 × 3.5 cm.) containing 80 ml. of water was placed on a magnetic stirrer and a 2-cm. bar magnet was dropped into the jar. The contents of the jar were illuminated from one side by a lamp through a slit. With the stirrer running at full speed 16 g. of salt were tipped in and a stop watch was started. The jar was closed with a rubber bung carrying a tube connected to a vacuum reservoir through a two-way tap. The tap was immediately turned to connect the jar to the vacuum and after 5 to 10 sec., when air in the solution had been removed, it was turned again to release the vacuum. Observation of the salt suspension was then commenced. Some 15 to 20 sec. after the addition of the salt there was a rapid clearing of the solution, showing that the majority of the salt crystals had dissolved. The rate of stirring was then reduced to a speed just sufficient to keep the crystals suspended, and the time at which the last crystals disappeared was noted. The end point was not sharp but could be determined to the nearest 5 sec. Results are given in Table 2.

TABLE 2. RATE OF SOLUTION OF SALT SAMPLES

Sample	Time to Dissolve
	sec.
A	40–45
B	35
C	30–35
D1	25–30

The rates of solution were in the same order as the average particle size found by microscopic examination and by sieving tests.

From a consideration of all the above results it seems most unlikely that a change from salt C to salt A would reduce the incidence of spotted colour. The difference in solution rates between these salts would tend if anything to have the reverse effect.

A change from salt B to salt D1 could possibly cause an improvement, but as the difference in solubility rates is small it is quite likely that here, too, some other cause was responsible.

Factory Experiments on Incidence of Spotted Colour in Butter

METHODS

Buttermaking

Cream from one batch was treated in a Vacreator* and cooled and divided equally between three holding-vats each containing sufficient cream for one churning of about 170 lb. of butter. Except where the experiment required different treatments, parallel churnings were made under as nearly the same conditions as possible and were salted with the same percentage of salt (1.5% to 1.6%). From each churning there were packed two 56-lb. boxes, two 4-lb. boxes, and a number of 1 lb. pats. The pats were held at 40°F. and were cut and examined for spotted colour at 1, 2, 3, 6, 10, 14, and 21 days after manufacture. The boxes were held at 14°F. The 4-lb. boxes were examined at 1 and 2 months and the 56-lb. boxes at 4 and 8 months after manufacture.

Grading

Samples were examined for occurrence of spotted colour as follows:

The sample (1-lb. pat or 4-lb. block) was cut and the surface was scraped with a spatula. Samples from 56-lb. boxes were taken with a trier and the plug was scraped in the same way. The freshly exposed surface was inspected under a good light and, if no spots were observed, further layers of butter were exposed by repeated scraping. Intensity of spotted colour was expressed thus:

1. Occasional spots: Not more than 2 or 3 spots found in one section of a 1-lb. pat.
2. Slightly spotted: Spots more numerous than in (1) but usually small or faint.
3. Definitely spotted: Numerous obvious spots—as in Fig. 2.
4. Heavily spotted: Spots more pronounced than (3)—appearance commonly described as "measles".

The classifications "occasional" and "slight" indicated degress of spotted colour which would normally escape detection in commercial grading.

It was found that development of spotted colour was delayed by freezing the butter. Apparently in frozen butter diffusion of moisture is almost completely arrested, and most of the development of spots occurs only before the butter goes into cold storage or after it is removed.

In the tables of results the grading observations on each churning have been reduced to three headings:

1. Time in days after manufacture at which spots first appeared.
2. Intensity of spotted colour after butter had been held 14 or 21 days at 40°F.
3. Intensity of spotted colour after butter had been held in cold storage at 14°F. for 4 or 8 months and then kept for a few days at atmospheric temperature.

*"Vacreator" is the trade mark of the vacuum pasteurizer manufactured by Murray Deodorizers Ltd.

Determination of Moisture Content of Butter Granules (Internal Moisture)

The internal moisture was determined directly on the granules after they had been freed from adhering water by centrifuging. The details of the method were as follows:

Approximately 1 lb. of butter granules was removed from the churn as soon as the wash water had been run off. The granules were chilled by holding in a cabinet at 15°F. for about 30 min. or for a sufficient time to firm the granules but not to form ice crystals among them. An 8-in. centrifuge basket lined with filter paper was cooled at the same time. The granules were transferred to the basket, any aggregates being broken up as much as possible, and were centrifuged for 5 min. at 2,000 rev./min. The dried granules were removed, freed from adhering filter paper and pressed into a pat. Moisture determinations were made on samples drawn from this pat.

Results obtained by this method showed good reproducibility and good agreement with tests on granules that had been dried by being pressed between sheets of filter paper. The average moisture content found was about 10%. This value corresponds to the average figure of 9.4% quoted earlier (McDowall and McDowell[7]) for buttermilk content of New Zealand commercial butter. It appears, therefore, that the removal of external water from the granules was reasonably complete, and hence the values obtained can be taken as a good indication of the amount of water which would be unavailable for solution of salt in the churn.

Results

Condition of Salt when Added to Churn

Salt is normally sieved or passed through a crushing machine before it is added to the churn. Some trials were made to determine whether careless work resulting in incomplete removal of lumps of salt would cause spotted colour in butter. At the same time an investigation was made of the relative value of "dry salting" and "wet salting". In the latter method enough water is added to the salt to make it into a paste or slurry before it is added to the butter.

The results of experiments with lumpy salt are set out in Table 3. For the first experiment (3/1) salt as it came from a bag in normal condition (i.e. slightly damp and with only a moderate amount of caking) was sieved and the lumps of salt retained on the sieve were added to the butter either in a dry state or after being wetted. These lumps were readily crumbled. Harder lumps of salt were produced for use in experiments 3/2 and 3/3 by thoroughly wetting a bag of salt and then drying it out in a warm room.

In experiment 3/1 spotted colour was absent in the butter salted with sieved salt or wet lumps of salt and only slight colour irregularities were found in the butter salted with dry lumps of salt.

Experiment 3/2 indicated a little more tendency for development of spotted colour in butter salted with wet lumps than with dry lumps. The butter salted with sieved salt did not develop spotted colour till after storage.

TABLE 3. EFFECT OF CONDITION OF SALT USED ON INCIDENCE OF SPOTTED COLOUR IN BUTTER

Exp. No.	Salt Used	First Moisture Test %	Salt in Butter %	Spots First Detected	Spots at 14 days	Spots after Storage
3/1	Seived, dry	15.3	1.60	—	nil	nil
	Lumps, wet	14.85	1.52	—	nil	nil
	Lumps, dry	15.0	1.52	8 days	occasional streaks	occasional
3/2	Sieved, dry	15.1	1.64	—	nil	definite
	Lumps, wet	14.9	1.48	5 days	slight	definite
	Lumps, dry	15.0	1.56	7 days	very slight	slight
3/3	Sieved, dry	15.6	1.52	—	nil	nil
	Lumps, wet	15.6	1.36	11 days	slight	sl.wavy
	Lumps, dry	14.0	1.48	5 days	heavy	heavy

In experiment 3/3 slight spotted colour occurred where salt was added as wet lumps but not with sifted salt. The churning to which dry lumps were added developed heavily spotted colour but the first moisture test for this churning was much lower than for the other two churnings and the comparison was therefore invalidated.

It was concluded that, while presence of lumps in the salt used could cause a slightly increased tendency to spotted colour, the difference was so small that only the most gross carelessness in preparing salt in a factory could have a significant effect on the incidence of spotted colour in the butter. There was no evidence that wetting the salt before it was added to the churn was of any advantage even though this treatment caused the lumps to crumble.

TABLE 4. EFFECT OF WET v. DRY SALTING ON INCIDENCE OF SPOTTED COLOUR IN BUTTER

Exp. No.	Salt Used	First Moisture Test %	Salt in Butter %	Spots First Detected	Spots at 14 days	Spots after Storage
4/1	Sieved, dry	15.0	1.56	6 days	very slight	occasional
	Sieved, moist	15.2	1.56	6 days	very slight	occasional
	Sieved, wet	15.1	1.44	6 days	very slight	very slight
4/2	Sieved, dry	14.3	1.60	3 days	definite	definite
	Sieved, moist	14.4	1.52	3 days	definite	slight
	Sieved, wet	14.4	1.44	3 days	definite	definite
4/3	Sieved, dry	14.6	1.72	8 days	slight	slight
	Sieved, wet	14.5	1.56	6 days	slight	very slight

A comparison of wet and dry salting techniques with normal sieved salt was made in a further series of experiments (Table 4). A third modification (moist salt) was introduced in these trials to find whether there was any justification for the belief common among factory managers that salt which had become damp through storage was less likely to give rise to spotted colour than dry salt.

For these experiments one portion of the salt was oven-dried, sieved, and kept dry until added to the churn. A second portion was held in an atmosphere saturated with water vapour until its water absorption had reached a maximum. A third portion was mixed the day before use with enough water to form a stiff paste.

In experiment 4/1, all three churnings developed the same slight degree of spotted colour. In experiments 4/2 and 4/3, the first moisture was intentionally brought lower for all churnings so as to increase the likelihood of spotted colour. Again there was no significant difference in incidence of spotted colour between churnings. It would appear, therefore, that there is no advantage in wet salting or in allowing salt to become damp before use.

Time of Contact between Salt and Granules

After the salt has been added to the granules it is usual to run the churn for a few revolutions with the workers disengaged, in order to mix the salt thoroughly with the granules. The churn may then be left stationary for a short period so that solution of salt is complete before working is commenced. There is considerable variation in the time allowed in commercial factories. In some the churn may be left for over 5 min. while in others the working is commenced immediately the salt has been mixed into the granules.

In the Institute factory the small size of the churn used renders special precautions necessary. As the ratio of area of churn walls to weight of butter is much higher than in a commercial 50- or 100-box churn, a greater proportion of the water is retained on the wooden surfaces, leaving less available to dissolve the salt. Under these circumstances is is usually considered necessary to allow a dissolving time of 15 min.

A series of experiments, the results of which are shown in Table 5, was made to find the effect of variation in time allowed for solution of salt. In the same experiments a comparison was made of the effect of using salt that had been milled to 100–200 mesh with that of normal vacuum butter salt.

In all churnings the salt and granules were mixed by revolving the churn in low gear for one minute with the workers disengaged. The churn was then left for the dissolving period indicated in Table 5.

The first moisture values in these experiments were unfortunately rather irregular, rendering some of the comparisons invalid. For example, in experiment 5/4 the low moisture content of the first churning caused the development of much more intense spotted colour than in the second churning although the time for dissolving the salt was 15 min. with the first churning and nil with the second.

With this exception, the second churning (holding time nil) always developed a much more intense spotted colour than the first (holding-time 15 min.). The lower moisture contents in the second churnings may, however, have contributed to the colour defects.

Use of Finely Ground Salt

Churnings with finely ground salt, although made without any period of holding for dissolving the salt, in no case showed significant colour defects even when the moisture content was low. A faint streaky colour was sometimes observed, but the streaks were of infrequent occurrence and were too faint to be readily detected.

TABLE 5. EFFECT OF TIME ALLOWED FOR SALT TO DISSOLVE

Exp. No.	Type of Salt	Time to Dissolve (min.)	First Moisture Test %	Salt in Butter %	Spots First Detected	Spots at 21 days	Spots after Storage
5/1	Normal	15	14.1	1.64	—	nil	nil
	„	nil	13.9	1.60	2 days	definite	definite
	Fine	nil	15.5	1.56	—	occasional streaks	occasional streaks
5/2	Normal	15	15.1	1.52	—	nil	nil
	„	nil	14.4	1.56	7 days	slight	slight
	Fine	nil	13.6	1.60	—	nil	nil
5/3	Normal	15	14.9	1.72	15 days	occasional	slight
	„	nil	13.4	1.64	3 days	definite	heavy
	Fine	nil	13.8	1.56	—	occasional streaks	nil
5/4	Normal	15	13.9	1.60	3 days	definite	definite
	„	nil	15.5	1.72	3 days	slight	slight
	Fine	nil	14.7	1.64	—	occasional	occasional

Extent of Draining of Churn

In order to show the effect of variations in moisture content of butter at salting, two trials, each of three churnings, were made as follows:

Churning No. 1: Churn very incompletely drained
„ No. 2: Churn more completely drained
„ No. 3: Churn very thoroughly drained.

Determinations of moisture content of granules (internal moisture) and of total moisture before addition of make-up water were made on all churnings. These results together with the values for free moisture (difference between total and internal moisture contents) are set out in Table 6. The results show a clear connection between the proportion of free moisture and the incidence of spotted colour. Where the free

moisture was less than 4%, spotted colour developed but where it was 5 or 6% the butter remained free from colour defects. The water required to dissolve 1.55% of salt (the average amount present in the butter) is 4.3%. The results therefore tally with the theoretical figure.

TABLE 6. EFFECT OF EXTENT OF DRAINING OF CHURN

Exp. No.	First Moisture Test %	Moisture in Granules %	Free Moisture %	Salt in Butter %	Spots First Detected	Spots at 21 days	Spots after Storage
6/1	16.25	10.25	6.0	1.60	—	nil	nil
	14.05	10.1	3.95	1.52	3 days	slight	slight
	13.6	10.0	3.6	1.56	3 days	definite	definite
6/2	16.2	10.35	5.85	1.56	—	nil	nil
	15.0	10.3	4.7	1.52	6 days	very slight	occasional
	13.6	9.9	3.7	1.56	1 day	heavy	definite

Coating of Salt with Fat

Too high a churning temperature has been stated to be one cause of spotted colour in butter. A suggested explanation is that where the granules are soft and greasy the salt crystals may become coated with fat and their dissolution delayed (McDowall[3]).

In order to test this hypothesis, a part or all of the salt used for some churnings was treated with enough melted butterfat to fill all the spaces between the salt crystals.

The results of this experiment (Table 7) show that treatment of one-quarter of the salt with fat had very little tendency to produce spotted colour in the butter. Butter from both churnings in which all the salt was treated developed a definite spotted colour. With both of these churnings, however, the first moisture was low and this may have contributed to the result obtained.

TABLE 7. EFFECT OF TREATING SALT WITH BUTTERFAT

Exp. No.	Salt Treatment	First Moisture Test %	Salt in Butter %	Spots First Detected	Spots at 21 days	Spots after Storage
7/1	Normal	13.9	1.52	5 days	slight	definite
	¼ fat-treated	15.2	1.40	—	nil	nil
	All fat-treated	13.2	1.32	2 days	definite	heavy
7/2	Normal	14.7	1.56	—	nil	nil
	¼ fat-treated	14.8	1.52	14 days	slight	slight
	All fat-treated	14.3	1.48	3 days	definite	heavy

It appears that any tendency for the salt to become greasy where the churning temperature is high would have only a slight effect on the rate of solution of the salt.

Churning Temperature

Some trials were made of the effect of different churning temperatures on the incidence of spotted colour in the butter. Owing to the great difference in consistency of butter granules churned at different temperatures, however, it was found to be impossible to judge the extent of draining required to bring all comparable churnings to the same moisture content. It was decided, therefore to limit the trials to a determination of the effect of churning temperature on the moisture content of the butter granules.

The results of these experiments (Table 8) showed that a higher churning temperature increases the moisture content of the granules and will therefore reduce the amount of water free to dissolve the salt.

TABLE 8. EFFECT OF CHURNING TEMPERATURE ON MOISTURE CONTENT OF BUTTER GRANULES

Exp. No.	Churn No.	Churn Temperature °F.	Churn Time min.	Moisture Content of Granules %
8/1	1	42.5	36	9.09
	2	46.5	23	9.43
	3	49	21	9.65
8/2	1	40.5	46	8.87
	2	45.5	36	9.36
	3	50	17	9.81
8/3	1	44	58	9.28
	2	48.5	23	11.37*
	3	52	26	10.15
8/4	1	44	76	9.32
	2	49	40	9.83
	3	52	43	9.91
	4	54	25	10.15

*Owing to unexpectedly short churning time these granules were churned to $\frac{1}{2}$–$\frac{3}{4}$ in. diameter instead of $\frac{1}{4}$ in.

Method of Cooling Cream

Three methods which had been found to give butters differing considerably in hardness were selected for comparison:

1. Cream was taken from the cooler at the temperature (49°F.) at which it was to be churned and was held at that temperature overnight (normal method).
2. Cream was cooled only to 60°F. on the cooler. The temperature was reduced slowly in the holding vat to 49°F.
3. Cream was held overnight at 60°F. and was cooled to 49°F. immediately before churning.

Slow cooling as in (2) or higher holding temperature as in (3) yields a cream in which the fat is less completely crystallized at churning. The resultant butter contains a greater proportion of free oil and is therefore softer (Dolby[10]).

The results given in Table 9 show that both temperature treatments designed to produce softer butter increased the internal moisture content of the granules. They appear, however, to have had opposite effects on the way the granules drained, since the first moisture tests differed considerably though all churnings were drained in the same manner. The incidence of spotted colour in the butter was correlated closely with the amount of free moisture.

TABLE 9. EFFECT OF COOLING TREATMENT OF CREAM ON MOISTURE CONTENT OF GRANULES AND INCIDENCE OF SPOTTED COLOUR IN BUTTER

Exp. No.	Cream Treatment	First Moisture Test %	Moisture in Granules %	Free Moisture %	Salt in Butter %	Spots first Detected	Spots at 21 days	Spots after Storage
9/1	Held and churned at 49°F.	14.5	10.0	4.5	1.60	6 days	slight	slight
	Slowly cooled to 49°F.	14.2	11.0	3.2	1.60	3 days	definite	definite
	Held at 60°F. churned at 49°F.	16.4	11.0	5.4	1.44	15 days	occasional	occasional
9/2	Held and churned at 49°F.	14.4	10.7	3.7	1.68	3 days	definite	definite
	Slowly cooled to 49°F.	14.1	11.0	3.1	1.60	3 days	heavy	heavy
	Held at 60°F. churned at 49°F.	15.4	11.1	4.3	1.60	8 days	slight	occasional

Fat Content of Cream Churned

Variations in fat test of cream churned may influence the percentage of water held in the granules. Mulder[6] found that internal moisture in butter from 9% cream was considerably higher than in that from 25% cream. Variations in test of cream churned commercially in New Zealand are not likely to be large since the average fat content of farm-separated cream as received at the factory does not vary much from 38–40%. Some reduction of fat test may, however, occur through dilution in processing or by inclusion of rinsings. A variation in the other direction may occur where part of the supply is factory-separated cream, which may contain 45–48% fat.

The effect of diluting cream to varying extents by addition of water in the holding vats was investigated (Table 10). The fat test had a very pronounced influence on the moisture content of the granules, the lowest test giving the highest "internal moisture" content.

TABLE 10. EFFECT OF CREAM TEST ON MOISTURE CONTENT OF GRANULES AND ON INCIDENCE OF SPOTTED COLOUR IN BUTTER

Exp. No.	Fat in Cream %	First Moisture Test %	Moisture in Granules %	Free Moisture %	Salt in Butter %	Spots First Detected	Spots at 21 days	Spots after Storage
10/1	44.5	13.9	9.7	4.2	1.56	8 days	slight	very slight
	39	14.6	10.6	4.0	1.64	3 days	slight	very slight
	35	14.8	10.9	3.9	1.48	3 days	slight	slight
10/2	41	14.4	10.4	4.0	1.60	3 days	definite	definite
	36	15.1	11.0	4.1	1.52	3 days	definite	heavy
	31	15.6	11.7	3.9	1.44	6 days	definite	definite

All churnings were drained to the same extent and, as the external moisture tended to remain the same in each of the churnings compared, there was no difference in the incidence of spotted colour.

Vacreator Treatment of Cream

A comparison was made of the effects of Vacreator treatment and of flash pasteurization of cream on the water content of the butter granules churned under similar conditions. The butters were not examined since the effect of internal moisture in granules on incidence of spotted colour had already been clearly established.

TABLE 11. MOISTURE CONTENT OF BUTTER GRANULES CHURNED FROM VACREATOR-TREATED AND FLASH-PASTEURIZED CREAM

Fat Test of Cream Churned %		Moisture in Granules %		
Flash	Vacreator	Flash	Vacreator	Difference
39	38	8.6	9.9	1.3
39	36	8.7	9.8	1.1
41	39	8.9	10.3	1.4
38	35	9.0	10.3	1.3

The comparisons given in Table 11 show that granules from Vacreator-treated cream regularly had over 1% more moisture than granules from flash-pasteurized cream. Dilution occurring in the Vacreator (indicated by lower fat tests on the pasteurized cream) would account for part but only a small part of this difference.

An investigation of the effect of intensity of Vacreator treatment (Table 12) showed that cream treated at medium or high intensity yielded granules of higher moisture content than did cream treated at low intensity.

Size of Butter Granules

Parallel churnings in which the cream was churned to different sized granules (Table 13) showed that internal moisture content tended to increase with the size of the granules.

TABLE 12. EFFECT OF INTENSITY OF VACREATOR TREATMENT ON MOISTURE CONTENT OF BUTTER GRANULES

Fat Test of Cream Churned %			Moisture in Granules %		
Low Intensity	Medium Intensity	High Intensity	Low Intensity	Medium Intensity	High Intensity
37	38	38	9.9	11.0	10.9
37	37	37	10.4	10.9	10.7

TABLE 13. EFFECT OF SIZE OF BUTTER GRANULES ON MOISTURE CONTENT OF GRANULES

	Moisture in Granules %		
	$\frac{1}{8}$ in.	$\frac{1}{4}$ in.	$\frac{1}{2}$ in.
	9.15	9.25	9.55
	8.95	9.2	9.2
	8.95	9.6	9.45
Average	9.0	9.35	9.4

Wash-water Temperature

This was not found to have any significant effect on the moisture content of the granules (Table 14).

TABLE 14. EFFECT OF WASH-WATER TEMPERATURE ON MOISTURE CONTENT OF BUTTER GRANULES

Wash-water Temperature	Moisture in Granules
At churning temperature	9.95
At 5°F. below churning temperature	9.95
At 10°F. below churning temperature	10.15

Differences in wash-water temperature will, however, alter the draining characteristics of the granules and so may affect the total moisture content.

Seasonal Variations

The moisture contents of granules from normal churnings in the Institute factory were determined at intervals through one season. Results for any churnings in which conditions, e.g. cream treatment, fat test, churning temperature or size of granules, were such as to give abnormal moisture contents, were discarded. The data have been plotted in Fig. 5. The average moisture content during the spring months was 9% but there was a steady increase until December when the average was over 10%. The number of normal churnings available later in the

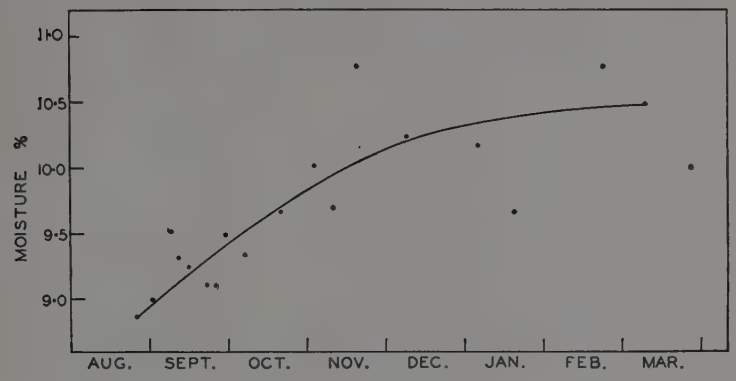

Fig. 5.—Seasonal variation in moisture content of butter granules.

season was insufficient to give an accurate indication of the trend in late summer and autumn. The information available shows, however, that seasonal variations in moisture content of granules do occur. These variations may explain "outbreaks" of spotted colour where there has been no change in manufacturing conditions.

CONCLUSIONS

It appears that the variations in crystal size occurring in vacuum dairy salt in normal use in New Zealand are not sufficiently great to cause significant differences in rate of solution and so to influence incidence of spotted colour in butter. Fine-milled salt, however, has a definite advantage since it can be used safely under conditions in which unmilled salt would give rise to spotted colour in butter. Owing to the speed with which this salt cakes, a fresh supply must be ground each day.

While the technique of salting is obviously important in that the salt should be well distributed in the churn and should be given a sufficient time to dissolve, it is possibly less important than the amount of water present. There does not seem to be any advantage in "wet salting" or in allowing the salt to become damp before use. A free-running dry salt can be more evenly distributed over the granules.

The most important factor in ensuring complete solution of the salt is the proportion of "free water" present in the churn at the time the salt is added, i.e., the quantity of water which is not enclosed as fine droplets within the granules. When the free water is in excess of that required to form a saturated solution of the salt used, considerable liberties in salting technique may be taken with impunity. When the amount of free water is less than that needed to dissolve all the salt, even the most stringent precautions in salting will be ineffective in preventing the appearance of spotted colour in the butter.

The buttermaker can regulate the total moisture at salting by the extent of draining the churn. He also has some control of the internal moisture content through adjustment of churning temperature and size of granules. Where he has to deal with a cream of low fat test or one

which has been subjected to intense Vacreator treatment, however, he may still have difficulty in reducing the moisture content of the granules to a sufficiently low value, particularly at times of the season when the characteristics of the cream tend to cause the internal moisture to be high.

The mechanism by which variations in internal water content of granules are brought about is not clear. Mulder (loc.cit.) has suggested that hard fat globules will pack less closely and thus enclose more water than soft fat globules. It has been found in the present investigation, however, that conditions likely to cause the fat globules to be soft, viz. high churning temperatures (Table 8) and less complete crystallization (Table 9), increases the moisture content of the granules. Since the first step in churning is the cementing together of the fat globules by liquid fat which could fill all the spaces between them (King and Fritz[11]), it seems unlikely that the closeness of packing of the globules would determine, as Mulder suggests, the amount of water enclosed. On the other hand, since the internal water is present as droplets emulsified in the liquid fat, an increase in the amount of liquid fat in the granules could well increase the quantity of water taken up. A less complete crystallization of fat in cooling the cream, or a higher churning temperature, would increase the amount of liquid fat in the granules and hence their internal water content.

It is possible that the size of the fat globules is also of importance. Treatment of cream in the Vacreator reduces the average size of the globules and also tends to increase the water content of butter granules. A decrease in globule size will result in an increase in surface area of globules and possibly an increase in the amount of water associated with globule membranes.

The remedies that should be applied where spotted colour occurs may be summarized:

1. Take care to ensure even distribution of salt in the churn and thorough mixing of salt with granules.
2. Allow adequate time of contact of salt with granules before working is commenced.
3. Keep total moisture content ("first moisture") as high as possible.
4. Keep dilution of cream to a minimum.
5. Lower the churning temperature.
6. Churn cream to smaller granules.
7. Reduce the percentage of salt added.
8. Where spotted colour occurs frequently and the above measures are ineffective: Install a salt-grinding mill.

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THE EFFECT ON AN ESTABLISHING PASTURE OF SPRAYING WITH SODIUM 2-METHYL-4-CHLOROPHENOXYCETATE

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Summary

A weedy pasture arising from a light autumn seeding was sprayed in its first spring with 0.75 lb. acid equivalent of MCP as sodium salt.

Yield measurements were made, over a period of four months, to compare sprayed and unsprayed pasture, both grazed and ungrazed.

Spraying reduced weeds rapidly, but both red and white clovers were damaged, the latter severely. There were no significant differences in total yield.

Problems in technique, clover tolerance, and secondary effects are discussed.

Introduction

Sears (1950) and Brougham (1954) have stressed the importance for successful pasture establishment of vigorous clover seedling growth, especially where the seeding has been light. Clover seedling vigour and survival are determined largely by competition from other species; thus it is desirable that weeds be eliminated at an early stage.

The destruction of weeds without concurrent damage to clovers appears possible using selective weedkillers, but little information is available on their effect on establishing pasture.

The opportunity was taken to make a quantitative study of the effect of spraying a weedy new-sown pasture with sodium 2-methyl-4-chlorophenoxyacetate (sodium MCP) under grazing.

Method

An autumn-sown dairy-farm pasture establishing in relatively fertile soil from a light seeding (20 lb./acre short-rotation ryegrass, 6 lb. red clover, 2 lb. white clover) undersown with a bushel of barley, had become invaded by weeds, which included: *Rumex obtusifolius* L., *R. crispus* L., *Ranunculus parviflorus* L., *R. repens* L., *R. sardous* Crantz., *Sisymbrium officinale* (L) Scop., *Cerastium glomeratum* Thuill, *Cirsium arvense* (L) Scop., *Sonchus oleraceus* L., *Juncus* spp., *Poa* spp., *Holcus lanatus* L.

Just before spraying, the pasture was close grazed by milking cows. The clovers were at the 4–5 trifoliate leaf stage of development. The spraying day (16 September 1953), and the three days following, were warm and overcast with a light breeze and periodical light drizzle. Through low-volume equipment 0.75 lb. acid equivalent of MCP, in 13 gal. water per acre, was applied to the pasture.

The four treatments were:

A. Protected from spray and from stock.
B. „ „ „ „ grazed
C. Sprayed and protected from stock.
D. „ „ grazed.

Nine replications (each 5 × 20 yd. see Fig. 1) were arranged across the pasture in three separate rows of three.

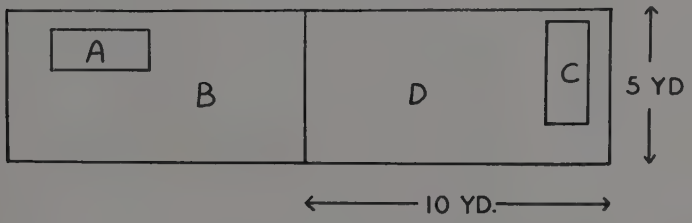

Fig. 1.—A typical replicate.

The unsprayed plots were protected by tarpaulins during spraying. Plots were protected from grazing by permanently sited frames, each 4 ft. × 10 ft., while grazed plots were sampled using frames moved within the plot area after each grazing. Dry weight and botanical composition of herbage were obtained for each frame at each grazing and the data analysed statistically. During the trial the pasture was grazed and sampled six times, 14, 38, 52, 68, 81, and 100 days after spraying: a total period of just over 14 weeks. Point analyses were performed before spraying 14+, 38+, and 68+ days after spraying, using the method of Levy and Madden (1933).

The trial concluded on 28 December 1953.

RESULTS

Both *Ranunculus* spp. and *Sisymbrium officinale* wilted within 6 hours of spraying and showed twisting within 24 hours. After 14 days *Ranunculus* spp. showed severe club distortion at the crown and rotting of the roots. In a subsequent wet period a few of these plants re-established but most died. Unsprayed *Sisymbrium officinale* commenced to move from vegetative to reproductive growth eight days after spraying and sprayed plants were dead within 14 days. *Rumex* spp. after 8 days showed some marginal scorch on the leaves but many of the plants survived. Eight days after spraying the petioles of red clover were distorted more than those of white clover, but towards the end of the trial it became evident that red clover had been affected less severely than white clover. The sprayed pasture became open, and weed grasses, including *Poa* spp. and *Holcus lanatus*, increased.

The changes in botanical composition of the pasture are indicated in Table 1.

At the time of the first sampling, the effect of spraying was masked by the presence of dead sprayed plants which had not disintegrated and as a result contributed to yield. The data for this sampling are not presented.

TABLE 1. PERCENTAGE COMPOSITION OF DRY HERBAGE AND TOTAL YIELD (lb./ac.)

	Time from spraying (days)	Short-rotation ryegrass	Red clover	White Clover	Other grasses	*Ranunc.* spp.	*Rumex* spp.	Other spp.	Total yield
A	38	68.1	2.3	2.5	8.1	10.3	1.1	7.6	1355
	52	74.3	5.6	3.7	3.0	10.4	0.7	2.3	569
	68	74.7	7.6	2.8	5.1	8.1	0.9	0.8	844
	81	69.3	12.6	7.2	4.7	5.1	0.9	0.2	573
B	38	66.9	0.9	1.9	10.6	11.1	1.8	6.8	1596
	52	72.1	3.2	1.0	6.3	13.4	0.7	3.3	1363
	68	79.4	2.0	1.5	3.7	11 0	2.0	0.4	15.4
	81	77.5	3.5	6.1	2.8	9.0	0.9	0.2	1302
C	38	85.4	1.5	1.1	10.6	0.7	0.7	—	1188
	52	86.0	2.5	1.1	8.1	1.2	0.7	0.4	730
	68	89.2	2.1	0 9	7.4	0.1	0.3	—	776
	81	82.6	7.8	2.0	6.6	0.4	0.2	0.4	498
D	38	80.5	0.7	0.5	17.1	0.9	0.3	—	1210
	52	84.4	2.6	0.7	7.8	2.1	2.4	—	1002
	68	84.7	1.5	0.1	11.4	1.5	0.8	—	1426
	81	82.9	6.8	1.8	7.4	0.2	0.6	0.3	942

A. Not sprayed, not grazed. B. Not sprayed, grazed. C. Sprayed, not grazed. D. Sprayed, grazed.

TABLE 2. ANALYSIS OF VARIANCE OF DRY-WEIGHT YIELDS OF RED AND WHITE CLOVER (g/plot)

Source of Variation	d.f.	F required 5% (1%)	Mean squares and results of tests					
			Red clover		White clover		Total clover	
Blocks	8	2.36 (3.36)	326	—	321	—	862	—
Spray (S)	1	4.26 (7.82)	1185	p=0.06	3741	**	9136	**
Grazing (G)	1	,, ,,	218	—	30	—	86	—
S × G	1	,, ,,	680	—	94	—	269	—
Residual 1	24		297		140		738	
Time of sampling (T)	3	2.70 (3.98)	1501	**	775	**	3762	**
T × S	3	,, ,,	81	—	367	**	229	—
T × G	3	,, ,,	245	—	284	*	665	—
T × S × G	3	,, ,,	230	—	105	—	42	—
Residual 2	96		140		77		288	
Coefficients of Variation			81.5%		98.9%		72.1%	

* significant at 5%
** ,, ,, 1%

TABLE 3. MEANS OF DRY-WEIGHT YIELDS OF RED AND WHITE CLOVER, WITH STANDARD ERRORS (lb./ac.)

		Red clover	White clover	Total clover
Not sprayed	Not grazed A.	49.9 ± 7.0	30.3 ± 4.8	80.2 ± 10.8
	Grazed B.	33.6 „	36.3 „	69.9 „
Sprayed	Not grazed C.	25.7 „	9.8 „	35.5 „
	Grazed D.	30.3 „	7.9 „	38.2 „
Not sprayed		41.8 ± 4.8	33.4 ± 3.4	75.2 ± 7.7
Sprayed		27.9 „	8.9 „	36.7 „
Not grazed		37.7 ± 4.8	20.2 ± 3.4	57.9 ± 7.7
Grazed		31.9 „	22.1 „	54.0 „
General Mean		34.8 ± 3.4	21.1 ± 2.4	56.0 ± 5.5

Clover Yield

The analyses of yields of red and white clovers are given in Tables 2 and 3.

The red clover analysis shows that spraying depressed red clover yield ($p = 0.06$), the effect being relatively constant for the whole experimental period. The higher yield of red clover in treatment A may be of importance. As the trial progressed, fertility in ungrazed treatments declined owing to lack of return of animal droppings.

White clover response was similar to the above except that the spray influence was more severe and prolonged. It varied from sampling

TABLE 4. ANALYSES OF VARIANCE OF DRY-WEIGHT YIELDS OF SOWN SPECIES AND WEEDS (g./plot)

Source of Variation	d.f.	F required 5% (1%)	Mean squares and results of tests		
			Sown species	Weeds	Total yield
Blocks	8	2.36 (3.36)	38,770 —	2,711 —	50,471 —
Spray (S)	1	4.26 (7.82)	20,953 —	86,240 **	192,210 *
Grazing (G)	1	„ „	864,125 **	79,995 **	1,469,955 **
S × G	1	„ „	64,644 —	8,312 —	119,298 *
Residual 1	24		22,948	2,237	27,363
Time of Sampling (T)	3	2.70 (3.98)	141,078 **	54,978 **	334,007 **
T × S	3	„ „	8,022 —	11,155 **	11,579 —
T × G	3	„ „	87,083 **	1,547 —	93,609 *
T × S × G	3	„ „	5,039 —	2,211 —	13,278 —
Residual 2	96		18,309	1,726	25,688
Coefficients of Variation			36.8%	56.1%	36.3%

to sampling being greatest 68 days after spraying. White clover yield of ungrazed treatments was greater, except at the last sampling when that of grazed treatments was greater, thus producing the significant T × G interaction.

The bulked or total clover yields showed a highly significant spray effect.

Yield of Sown Species

The analyses of yields of sown species and of weeds are given in Tables 4 and 5.

TABLE 5. MEANS OF DRY-WEIGHT YIELDS OF SOWN SPECIES AND WEEDS WITH STANDARD ERRORS (lb./ac.)

		Sown species	Weeds	Total yield
Not Sprayed	Not grazed A.	673.6 ± 60.8	162.1 ± 19.0	835.7 ± 66.3
	Grazed B.	1,147.8 „	312.2 „	1,458.8 „
Sprayed	Not grazed C.	718.0 „	80.4 „	798.4 „
	Grazed D.	938.1 „	157.3 „	1,145.4 „
Not sprayed		911.3 ± 43.0	236.5 ± 13.4	1,146.6 ± 46.8
Sprayed		852.5 „	118.9 „	971.3 „
Not grazed		696.4 ± 43.0	121.3 ± 13.4	816.4 ± 46.8
Grazed		1,067.4 „	234.1 „	1,301.5 „
General mean		881.3 ± 30.3	177.7 ± 9.4	1,059.0 ± 33.1

There was no significant difference due to spraying, damage caused by spraying being no greater than that caused by weed competition. Percentage composition (Table 1) showed ryegrass declining in importance in unsprayed plots. Nevertheless, the actual yields of sprayed and unsprayed plots were similar throughout. The effect of the grazing animal in increasing fertility was obvious.

Weed Yield

Both spraying and grazing treatments produced highly significant effects as shown by the F tests and means in Tables 4 and 5.

Weeds in treatment B were largely *Ranunculus* spp. and *Rumex* spp. while those in treatment D were mainly weed grasses which established in the bare spaces resulting from spraying. The spray effect changed with each grazing; a decrease of weeds in unsprayed treatments (Table 1) reduced the difference between weed herbage yields from sprayed and unsprayed plots.

Total Yield

The total herbage yield was reduced by spraying, particularly in grazed plots, but it was increased by grazing.

TABLE 6. PERCENTAGE GROUND COVERED BY EACH SPECIES 38+ AND 68+ DAYS AFTER SPRAYING (549 points per treatment)

	Not sprayed				Sprayed			
	Not grazed		Grazed		Not grazed		Grazed	
	38+	68+	38+	68+	38+	68+	38+	68+
Short-rotation ryegrass	65	67	70	77	76	72	72	82
Red clover	6	7	2	3	3	5	3	3
White clover	6	8	4	7	6	3	5	2
Other grasses	17	25	20	29	31	34	29	29
Ranunculus spp.	15	12	12	12	3	3	3	2
Rumex spp.	6	7	6	10	2	3	6	3
S. officinale	2	—	3	—	7	—	—	—
Cerastium glomeratum	1	—	1	—	—	—	—	—
Other species	2	3	1	2	—	2	1	2
Bare ground	4	2	6	2	—	3	7	5

Ground Cover

Ryegrass adopted a more prostrate habit of growth in sprayed plots and covered more ground. White clover behaved in a similar manner, but despite its greater spread it did not outyield red clover. The technique probably underestimated white clover in sprayed plots giving overemphasis to the spray effect. The observed increase of "other grasses" is confirmed. The *Ranunculus* spp. persisting in sprayed treatments were retarded in growth.

Dock cover was reduced by spraying and in ungrazed treatments.

TABLE 7. ANALYSIS OF VARIANCE FOR A DOCK COUNT MADE 105 DAYS AFTER SPRAYING (Nos. per sq. ft.)

Source of variation	d.f.	F required 5% (1%)	Mean squares and results of tests	
Blocks	8	2.36 (3.36)	560	*
Spray (S)	1	4.26 (7.82)	1431	*
Grazing (G)	1	,, ,,	4160	**
S × G	1	,, ,,	832	—
Residual	24		208	
Coefficient of variation			29.4%	

TABLE 8. MEANS FOR DOCK NUMBERS, WITH STANDARD ERRORS
(Nos. per sq. ft.)

Not sprayed	Not grazed A.	7.1 ± 1.6
	Grazed B.	4.0 ,,
Sprayed	Not grazed C.	4.9 ,,
	Grazed D.	3.7 ,,
Not sprayed		5.5 ± 0.8
Sprayed		4.3 ,,
Not grazed		6.0 ± 0.8
Grazed		3.8 ,,
General mean		4.9 ± 0.4

Docks

A count of dock plants, mainly seedlings, was made after the final grazing.

Grazing apparently gave better control of docks than spraying, but the time which elapsed from spraying to count was sufficient for a fresh set of seedlings to emerge, so that the actual effect of spraying was greater than indicated.

Discussion

The chief problem in the use of selective weedkillers on pastures is their harmful effect on clovers. The present study was undertaken to investigate not only the effect of MCP on weeds and clovers in an establishing pasture but also the secondary changes resulting from their decrease in number and vigour. The complexity of these changes when the pasture is defoliated, either by grazing or by clipping, is well illustrated by the results presented above. It is obvious that, despite the clear-cut trends which emerged, considerably more data are required before an adequate assessment is possible.

Spraying caused a rapid and spectacular decrease in weed content but docks were inadequately controlled. Spraying also caused such damage to clovers that their yield over the trial period declined by about 50%. Decrease in clover content of an establishing pasture has serious effects on its subsequent productivity, since lack of clovers inevitably results in an inadequate nitrogen supply for the associated grasses (Brougham 1954). Their poor growth, and the patches of bare ground due to death of weeds, leads to invasion by less valuable grasses such as *Poa* spp. and *Holcus lanatus*. Weed destruction by hormone-type weedkillers can be effective only if methods can be found for safeguarding the clover content and hence the nitrogen status of the pasture.

There is, however, a long-term effect of spraying which cannot be expressed in a short-term trial. Death or inhibition of weeds by weedkillers reduces reseeding and must eventually reduce weed seed populations.

The yield of sown species in the untreated pasture did not differ significantly from that of the sprayed pasture. Weed competition with the sown species offset the decrease in clover yield in the sprayed pasture, with its attendant effect on soil nitrogen levels.

The danger of using the mower or shears in weed control experiments is well demonstrated. A number of weed species in this trial are highly unpalatable to stock and their growth under grazing conditions is not retarded by periodic defoliation. The sampling method used was insufficiently selective, being especially severe on these unpalatable plants. In ungrazed treatments repeated samplings heightened the effect. The marked decrease in yield of weeds is due to the impossibility of reproducing the cow's eating habits by mechanical means.

Fertility fell, during the trial, in ungrazed treatments. It is very probable that the observed decline in yield of sown species was due to this influence. Had the trial been prolonged, a technique for proportional return of dung and urine would have been required.

The selective grazing of cows noted in this trial might have been different if sprayed treatments had occurred in unsprayed pasture rather than unsprayed in sprayed as here. Both arrangements should have been tested concurrently on the same pasture.

The quality of herbage from sprayed and unsprayed pasture differed little at the last sampling so that, had the trial been extended to six months, a clearer result might have been achieved.

The application of MCP used here caused appreciable damage to both red and white clovers, particularly the latter. This appears to conflict with Scragg's (1953) belief but agrees with Holly's (1953) findings wherein juvenile red clover was damaged less by Na salt of MCP than was white clover at comparable ages. Stryckers (1952) records that white clover is more easily killed by MCP than by 2,4-D, while others hold the opposite to be the case for red clover. As both clovers were at a similar stage of development, the relative hardiness of red clover cannot be attributed to its being more advanced. The slump in clover yield following MCP spray damage reported in Templeman's (1952) quantitative report is confirmed here. Numerous observations incline Allen (1953) to the view that in Britain recovery of clovers following "hormone" spraying requires about 12 months. This period is likely to be shortened in New Zealand. Possibly strain differences may explain anomalies in the behaviour of white clovers under MCP spray but the relatively rapid recovery of clovers in New Zealand is probably due largely to equable climate and a buried clover seed population (Hyde and Suckling 1953). A smaller application of MCP, or a delay in its application, might have reduced the damage to clovers.

Competition was active in unsprayed treatments. In sprayed treatments reduction of weeds cleared the way for vigorous ryegrass growth but the influence of the damage to clover restricted this. Weed grasses increased. The greater vigour of ryegrass plants in grazed treatments suggests that it may have been desirable to promote ryegrass growth with fertilizer. A further alternative would have been to "oversow" with clover seed. The total yield for the trial period showed that spraying was not beneficial but, by the prevention of weed reseeding and reduction of dock numbers, the potential performance of the pasture was enhanced. The imperfect control of docks by grazing animal and spray left the problem of this perennial weed unsolved.

Acknowledgements

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A COMPARISON OF THE MILK PRODUCTION OF COWS ON DIFFERENT SYSTEMS OF BREAK FEEDING

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(Received for publication, 29 December 1954)

Summary

There was no significant difference in the milk production of cows grazing pasture when fed one break per day from that obtained when they were given two breaks per day.

Introduction

Two problems arising in the feeding of dairy cows on pasture, namely the efficient utilization of pasture and the control of bloat, have focussed attention on break feeding (or grass rationing). From observation, it seems that cows graze an area of long grass much more efficiently if they are allowed on only a part of the area at a time than if they are allowed free range over the whole area, although no critical experimental work on this subject has yet been reported. A number of New Zealand dairy farmers have recently adopted systems of break feeding which they believe help to reduce the incidence of bloat in their herds. In some cases they give the cows four or more small breaks during a twenty-four hour period with the object of preventing them from obtaining rapidly a fill of pasture sufficient to cause bloat.

As different systems of break feeding are being more widely used for these reasons, it is of considerable interest to find how the production of cows subjected to them is affected. Changes in the feeding system may, by altering the grazing habits of the cows, affect their daily intake of pasture.

Review of Literature

The available literature on feeding dairy cattle contains few references to break feeding and none to experimental work on the subject.

The effect of feeding housed dairy cows once per day instead of twice was reported by Dawson and Kopland (1949). The cows gave a little more milk on two feeds per day, but it is not stated whether this difference of approximately 6% of the yield was statistically significant.*

Experimental Design and Methods

Twelve cows in two groups of six were used in a double reversal type of experiment covering three periods each of three weeks. These cows, which were all spring calvers that had been in milk for two to three months when the experiment commenced, were allotted to one of two groups at random, and the cows in the first group were given one break per day in the first and third periods and two per day in the second, while those in the second group followed the opposite sequence.

*Since this paper went to press, J. Hancock and C. P. McMeekan (1954, *J. Agric. Sci. 45:* 901) have reported a similar experiment in which cows were left on each grazing area for longer periods.

The pasture was mainly perennial ryegrass and white clover with a considerable proportion of cocksfoot and *Poa trivialis* and some other species in some of the paddocks. One paddock of short-rotation (H_1) and perennial ryegrass with red and white clover was also used. Only paddocks in which the growth of pasture appeared to be even from side to side were used, and during most of the experiment the grass was four to six inches high when it was grazed. Dry weather in the last period slowed pasture growth and the material grazed in the last period was dryer and shorter than that used earlier.

The soil in all the paddocks was free draining, and little wet weather was experienced while the trial was in progress.

The objects of the method of feeding used were to give the cows the same quantity of pasture each day and to ensure that any errors in this respect did not cause bias by giving cows on one treatment consistently more or less than those on the other. Small rectangular paddocks were split into two equal areas by a longitudinal fence on each side of which one group of cows was grazed. The cows were given their fresh break once or twice each day according to the treatment they were on, and because the breaks were narrow they were allowed to go back onto the previous day's area. However, they very seldom went off the freshest area available to them. The plan of changing groups from side to side of the paddock daily was considered to be desirable in helping to randomize effects of variations in the supply of grass, but could not be followed as the amount of feed left on the back area of each group would have been determined by the other group. As a compromise, the side of the paddock each group started on was determined at random and the groups changed sides half way down the paddock. In each period the cows changed paddocks five or six times.

The area given on any day was the same for both groups of cows, but was varied from day to day according to an eye estimation of the amount of grass available. The level of feeding was somewhat below *ad lib.* feeding. The cows would probably have eaten more grass had it been available, but the amount was reasonably liberal, and all the cows gained in body weight throughout the experiment.

The experimental design and feeding methods used were such that differences in the feed supply from day to day or between groups on any one day are not likely to have contributed much, if at all, to the comparison between treatments.

Results

The data for the first two periods were complete, but two cows in one group bloated in the third period, one of which died and the other had to be stuck with a trochar. These two cows were replaced to keep six cows in each group, and after allowing two days for the cows to settle down the experiment was continued. The production figures for the two replacement cows were not, of course, considered in the results, and the figures from the time the bloating occurred until the experiment was restarted were also ignored. The third period was extended to make up the complete twenty-one days, and in the analysis of the results missing data technique was used to calculate third-period figures for the two cows that had bloated.

Milk Yields

The milk yields for the cows are shown in Table 1.

TABLE 1. MILK YIELDS OF COWS FOR THREE-WEEK PERIODS

Group A Sequence 1-2-1 breaks per day				Group B Sequence 2-1-2 breaks per day			
Period Cow	I. lb.	II. lb.	III. lb.	Period Cow	I. lb.	II. lb.	III. lb.
T. 3	280	202	129	T. 4	679	682	604
T. 17	473	501	485	T. 18	769	787	
T. 22	680	691	658	T. 28	606	587	513
T. 27	638	640	569	T. 1	450	417	316
T. 55	686	698	608	T. 40	502	538	
T. 11	472	396	325	T. 14	507	488	415

The difference in milk yield attributable to treatment (0.48 lb. milk/cow/day) was well below the 5% level of significance.

Proportion of Milk Given at Different Milkings

The cows were milked twice a day and the milk yields were examined to see whether the different treatments caused different proportions of the daily milk yields to be given at these milkings. The difference was very small and not statistically significant.

DISCUSSION

From these results it appears that the effect, if any, of feeding one break a day instead of two was small and unimportant. This indicates that the cows got about the same amount of feed under the two different systems. As no measurements of pasture intake could be made it is not known whether cows on two breaks a day had more feed in the evening than when they were on one break a day, but if a difference did exist the buffering effect of the cow's rumen contents would be expected to even out the supply to the more distal portions of the alimentary canal.

Under different conditions, for instance, different planes of nutrition or on different soil types where damage due to pugging is greater, there may be some advantage as far as production is concerned in feeding two breaks a day instead of one.

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APPLE ROOTSTOCK TRIALS

II. DOUGHERTY ON EAST MALLING, MERTON, AND LOCAL ROOTSTOCKS

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(Received for publication, 21 December 1954)

Summary

The growth and cropping of Dougherty on twelve rootstocks is described for ten years following planting. Rootstocks included:—

Malling XII, XIII, XV, and XVI.
Merton 778, 779, 789 and 793.
Local selections H/1/26, N/1/19.
Large's No. 1 and Northern Spy No. 1.

The most vigorous stocks were Large's No. 1, M.XII and Merton 779, all of which produced large trees. Total production of fruit for the ten-year period was highest on Merton stocks 779, 789, 793, and Northern Spy No. 1, yields on these four being similar.

Trees on M.XIII and Merton 789 proved susceptible to apple collar rot (*Phytophthora cactorum* (Leb. & Cohn.) Schroet.) and these rootstocks are considered unsuitable for New Zealand orchards.

Merton 779 rootstock shows considerable promise for the production of vigorous, yet heavy-cropping trees.

Introduction

The original series of apple rootstock trials laid down in several districts in 1934 and at the Research Station, Auckland, three years later included only East Malling stocks and the local Northern Spy (Woodhead, 1946; Woodhead *et al.*, 1954). When trees were being propagated for these trials, the susceptibility of certain East Malling stocks to attack by woolly aphis (*Eriosoma lanigerum* Hausm.) soon became evident in the nursery. In 1941 therefore a more comprehensive trial was laid down which, in addition to the East Malling stocks, included four of the Merton aphis-immune rootstocks and a number of stocks of local origin. The location of the trial is the Department's research orchard at Oratia, a district near Auckland where many commercial apple orchards have been established on "gumland" soils typically shallow clays of poor drainage.

In this paper an account is given of the performance of trees on the various rootstocks during the initial ten-year period.

Experimental Material and Method

Rootstocks included the following:

Malling XII, XIII, XV, and XVI.
Merton 778, 779, 789, and 793.
H/1/26, N/1/19, Large's No. 1 and Northern Spy No. 1.

The Malling stocks included all those represented in the district trials established seven years earlier, with the exception of M.I. This

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rootstock had given an early indication of lack of vigour and was therefore omitted from the present trial.

The Merton rootstocks are clonal stocks of Malling II × Northern Spy parentage, raised at the John Innes Institute, England, and described by Tydeman (1937). They are immune to woolly aphis.

Rootstocks H/1/26, N/1/19, and Large's No. 1 are clones raised by the senior author, following tests to ascertain their response to vegetative methods of propagation. Their origin is as follows:

H/1/26

Raised from root cuttings obtained from a vigorous Jonathan tree on an unknown stock at Stoke, Nelson.

N/1/19

Obtained as root cuttings from a Jonathan tree of outstanding growth at Earnscleugh, Otago.

Large's No. 1

Raised from one of a number of seedlings obtained from a Nelson nurseryman, whose source of seed was a local variety, Epps' Seedling.

Northern Spy No. 1, a selection made by Allan and Woodhead (1933), was the predominant type in a collection of Northern Spy stocks raised from root cuttings taken from mature trees in orchards throughout New Zealand. Northern Spy is a vegetatively propagated rootstock.

Dougherty, an important export apple, was used as the scion variety as, being a variety of moderate growth, it would be likely to give an early indication of differences in rootstock vigour. One-year-old budded trees were planted in 1941 at the Research Orchard, Oratia, Auckland, on a heavy, grey podzolized clay of poor drainage. The ground had been occupied previously by an orchard of young stonefruit trees.

The trees were planted on the square at 18 ft. spacing and in randomized blocks. There were seven replications of single-tree plots of all rootstocks with the exception of Large's No. 1 and Merton 789, of which there were only four replicates. During the year following planting, eight trees were lost from causes attributed to poor drainage. Losses included four trees on M.XIII and one on each of the rootstocks, Northern Spy No. 1, M.XVI, Merton 778, and Merton 789. As trees held in reserve were insufficient to replace all casualties, the number of replications of M.XIII and Merton 789 was reduced to four and three respectively. An additional tree on Large's No. 1 was planted on a vacant site, increasing the replications of this stock to five. The only subsequent casualty was a single tree on M.XIII in 1944. This was not replaced.

The trees were trained to three leaders and pruned on the "long lateral" system to encourage early cropping. Wood growth was strong in the earlier years, especially on the more vigorous stocks, and it is probable that a five-leader tree would have proved more suitable for this variety.

Clean cultivation was practised during the spring and summer, followed by an autumn-sown cover crop of lupins or oats. An annual

dressing of artificial manures was given. In 1942, field tiles were laid between the tree rows, resulting in a gradual improvement in drainage.

Tree growth was recorded annually from time of planting by measuring trunk girth at a fixed point, approximately 6 in. above the bud union, and tree height and spread, the latter being the mean of two measurements taken in fixed directions at right angles.

All fruit was weighed, including windfalls which were collected at weekly intervals as the crop approached maturity.

RESULTS AND DISCUSSION

In the statistical analysis of tree growth and crop data, the "missing plot" method was used for Large's No. 1 rootstock, of which there were only five replications. In the following tables, therefore, the difference required for significance between this stock and other rootstocks is shown separately. As only three trees survived on each of the stocks M.XIII and Merton 789, these rootstocks were not included in the statistical analysis and tables. The relevant figures are, however, given in the text. In 1951, all trees on these two stocks were found to be infected with the collar rot fungus (*Phytophthora cactorum* (Leb. & Cohn.) Schroet), consequently their growth and cropping in this trial may not be a true indication of the performance of healthy trees.

TABLE 1. AVERAGE TRUNK GIRTH, HEIGHT, AND SPREAD, OF DOUGHERTY ON TEN ROOTSTOCKS AT FOUR AND TEN YEARS FROM PLANTING

Rootstock	Trunk Girth (cm.)		Height (m.)		Spread (m.)	
	1945	1951	1945	1951	1945	1951
Large's No. 1*	16.1	40.4	2.7	4.9	1.1	3.4
M.XII	18.0	40.1	2.9	4.9	1.2	3.0
Merton 779	17.4	39.9	2.6	4.8	1.2	3.1
H/1/26	16.3	36.8	2.5	4.6	1.1	2.9
Northern Spy No. 1	15.8	34.7	2.5	4.4	1.1	3.1
Merton 778	16.0	34.2	2.3	4.3	1.1	2.9
M.XV	15.9	33.7	2.7	4.4	1.1	2.7
Merton 793	15.5	33.4	2.4	4.2	1.1	3.1
N/1/19	15.6	32.5	2.4	4.2	1.1	2.9
M.XVI	14.1	29.3	2.3	3.9	1.1	2.7
Difference for significance (Year 1951) at 5%		2.7		0.4		0.3
at 1%		3.6		0.5		0.4
*Difference for significance between Large's No. 1 and other stocks. (Year 1951) at 5%		3.1		0.4		0.3
at 1%		4.1		0.6		0.4

Rootstock Effect on Tree Growth

Tree growth on the various stocks at four and ten years from planting is shown in Table 1.

Fig. 1.—Dougherty on Large's No. 1 rootstock; planted 10 years. Cases represent average crop.

Photo: J. W. Endt.

Fig. 2.—Dougherty on M.XII; planted 10 years. Cases represent average crop.

Photo: J. W. Endt.

Considering trunk girth in conjunction with height of tree, the largest trees were produced by a group of three rootstocks, Large's

No. 1, M.XII, and Merton 779 (Figs. 1–3). Trees on H/1/26 were intermediate in size between these trees and those on the large group

Fig. 3.—Dougherty on Merton 779; planted 10 years. Cases represent average crop.

Photo: J. W. Endt.

of less vigorous stocks, as they are included in the first group for height but not for trunk girth. The consistent positive correlation between trunk girth and height evident in the table confirms the usefulness of trunk girth measurement as a record of vigour where only one growth measurement can be taken.

Growth measurements for rootstocks M.XIII and Merton 789, not included in Table 1, were

	Trunk Girth (cm.)		Height (m.)		Spread (m.)	
	1945	1951	1945	1951	1945	1951
M.XIII	13.5	31.8	2.3	4.3	1.0	2.9
Merton 789	16.1	31.3	2.5	4.0	1.1	3.1

Rootstock Effect on Cropping

Accumulated crop per tree from year to year for each of the ten rootstocks is shown in Table 2.

TABLE 2. ACCUMULATED CROPS (lb. per tree) OF DOUGHERTY ON TEN ROOTSTOCKS, 1941–51

Rootstock	1941–47	1948	1949	1950	1951
Merton 793	55.15	114.52	202.42	379.22	592.68
Merton 779	44.76	94.71	167.03	340.03	564.15
Northern Spy No. 1	44.95	91.94	176.94	330.17	544.81
Merton 778	39.10	78.07	149.08	271.65	460.39
N/1/19	41.08	95.99	151.89	286.50	439.84
Large's No. 1*	29.80	65.18	110.73	248.32	436.84
M.XII	33.13	73.01	123.09	239.93	424.38
H/1/26	30.60	63.08	114.32	237.61	389.95
M.XVI	31.29	73.78	131.17	246.97	389.74
M.XV	33.42	62.12	111.41	221.27	351.91
Difference for significance at 5%	12.06	26.51	38.08	67.17	98.40
at 1%	16.09	35.35	50.78	89.57	131.21
*Difference for significance between Large's No. 1 and other stocks at 5%	13.67	30.03	43.20	76.38	111.47
at 1%	17.97	40.04	57.50	101.84	148.63

It will be seen that the heaviest crops for the period were produced by trees on the Merton stocks 793 (Fig. 4) and 779 and on Northern Spy No. 1 (Fig. 5), there being no significant difference in yield between the three stocks. The heavy cropping of trees on 779 is especially noteworthy in view of their vigour, and is in marked contrast with that of the equally large trees on Large's No. 1 and M.XII.

Fig. 4.—Dougherty on Merton 793; planted 10 years. Cases represent average crop.

Photo: J. W. Endt.

Accumulated crops for the years 1941 to 1947 show that trees on the vigorous 779 were as precocious as the smaller trees on Northern Spy No. 1.

Fig. 5.—Dougherty on Northern Spy No. 1: planted 10 years. Cases represent average crop.

Photo: J. W. Endt.

Accumulated crops per tree on Merton 789 and M.XIII for the ten-year period were:—

	1941–7 lb.	1948 lb.	1949 lb.	1950 lb.	1951 lb.
Merton 789	53.56	116.52	211.90	352.71	585.71
M.XIII	24.04	57.39	92.92	193.98	355.79

Annual crops for the seventh to tenth years are given in Table 3.

TABLE 3. ANNUAL CROPS (lb. per tree) OF DOUGHERTY ON TEN ROOTSTOCKS

Rootstock	1948	1949	1950	1951
Merton 779	49.95	72.32	173.00	224.12
Northern Spy No. 1	46.99	85.00	153.23	214.64
Merton 793	59.37	87.90	176.80	213.46
Merton 778	38.97	71.01	122.57	188.74
Large's No. 1	35.38	45.55	137.59	188.52
M.XII	39.88	50.08	116.84	184.45
N/1/19	54.91	55.90	134.61	153.34
H/1/26	32.48	51.24	123.29	152.34
M.XVI	42.49	57.39	115.80	142.77
M.XV	28.70	49.29	109.86	130.64

From the figures for the final year it is evident that production is still increasing on all rootstocks. Relevant figures for annual cropping on Merton 789 and M.XIII are:—

	1948 lb.	1949 lb.	1950 lb.	1951 lb.
Merton 789	62	95	140	233
M.XIII	33	35	101	161

CONCLUSIONS

The results of this trial have shown that, with Dougherty as the scion variety, the rootstocks Merton 779 and Large's No. 1 are as vigorous as M.XII, a stock noted for production of large trees. Of other rootstocks included, none was significantly more vigorous than Northern Spy No. 1.

The most noteworthy feature of the trial is the heavy cropping of the large trees on Merton 779, an unusual combination of vigour and fruitfulness in young trees.

With production still increasing on all stocks, the ultimate cropping position of trees on different rootstocks cannot yet be determined, especially that of the vigorous trees on Large's No. 1, M.XII, and Merton 779. Although trees on three of the four Merton stocks were conspicuous for heavy bearing, on no stock was the yield significantly higher than on Northern Spy No. 1.

Malling XIII and Merton 789 appear unsuitable for New Zealand orchards because of susceptibility to apple collar rot.

Acknowledgements

The authors wish to express their thanks to Messrs A. Farmer and C. G. Aldridge, Fruit Research Station, and Mr. C. E. K. Fuller, a former member of the staff, for assistance in recording; also to Mr. W. B. Taylor, Applied Mathematics Laboratory, Department of Scientific and Industrial Research, for statistical analysis of the data.

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THE INFLUENCE OF L-THYROXIN UPON THE GROWTH AND SUBSEQUENT PRODUCTION OF IDENTICAL-TWIN DAIRY HEIFERS

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Summary

1. A hyperthyroid state was induced in six identical-twin heifers for approximately the first six months of their first pregnancy by the daily injection of l-thyroxin at the rate of 0.4 mg./100 lb. of body weight.
2. The hyperthyroidism induced by this level of l-thyroxin resulted in a depressed rate of gain of body condition and accelerated rate of skeletal growth.
3. The feed intake of the hyperthyroid animals was greater than that of their control mates, whereas their grazing time was actually less and the time spent in cudding was increased.
4. The subsequent milk and butterfat production of most of the animals subjected to l-thyroxin therapy was depressed.

INTRODUCTION

During the last twenty years a great deal of work has been carried out relating thyroid-active materials to the augmentation of established lactation, and a considerable amount of knowledge concerning the galactopoetic properties of this endocrine gland has subsequently accrued[1]. Yet little is known concerning the role that the thyroid hormone plays in mammary development.

In the rat, hypothyroidism results in the stimulation of lobule-alveolar growth and the suppression of duct growth, while in the mouse the usual growth response resulting from ovarian hormones is suppressed[2]. In the cow the situation is even more obscure. Recently, however, there have been reports[3 4] of mammary growth in non-pregnant, non-lactating females following thyroid administration. In consequence an experiment has been carried out with the object of determining whether the exogenous administration of l-thyroxin to dairy heifers during the first six months of pregnancy would cause greater growth of the mammary glands, this being reflected in a subsequent increased maximum milk yield. The opportunity was also taken of obtaining a measure of the influence of l-thyroxin upon the general growth and development of dairy cattle.

EXPERIMENTAL

Animals

Nine pairs of identical-twin yearling dairy cattle were selected such that they came into oestrus within a few days of each other. They were mated and one member of each set placed on a routine of daily thyroxin injections, these injections continuing for approximately six

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TABLE 1. TREATMENT DATA

Cow No.	Treatment	Date First Injection	Date Last Injection	Calving Date
T255	Thyroxin	16/10/51	15/4/52	27/7/52
T256	Control	—	—	21/7/52
T263	Thyroxin	16/10/51	15/4/52	23/7/52
T264	Control	—	—	4/8/52
T285	Thyroxin	16/10/51	14/4/52	3/8/52
T286	Control	—	—	2/9/52
T287	Thyroxin	16/10/51	14/4/52	28/7/52
T288	Control	—	—	12/7/52
T289	Thyroxin	16/10/51	7/6/51	19/10/52
T290	Control	—	—	26/7/52
T294	Thyroxin	23/10/51	23/4/52	29/7/52
T293	Control	—	—	15/10/52

months. Of these nine sets, only six conceived, so that the remaining three sets, one or other member of which proved not in-calf, were rejected from the experiment.

Hormone Treatment

L-thyroxin was administered daily in the form of a subcutaneous injection. During the first three weeks of treatment the dose rate was 0.5 mg./100 lb. live weight per day, this being reduced to 0.45 mg./100 lb. for the following month. Thereafter the dosage was reduced to 0.4 mg./100 lb. and continued at this rate for the remainder of the six months allocated as the treatment period. These dose rates were altered in order to produce a situation of mild hyperthyroidism only.

Heart Rate

At weekly intervals throughout the six months of treatment the heart rate was recorded. This was achieved by direct auscultation of the chest area, observations being made during four separate 30-second periods.

Growth

From the time the first injection was made, the measurements listed below were taken at weekly intervals throughout the following 20 months, i.e. up to the time of the second calving of these animals:

(a) Weight (lb.)
(b) Chest girth (cm.)
(c) Belly girth (cm.)
(d) Height over withers (cm.)
(e) Hip-hip (cm.)
(f) Hip-pin (cm.)

Grazing Observations

Grazing observations were made on the initial nine pairs of animals during the second month of treatment. Four times during this month the animals were watched throughout 24-hour periods, and the following observations recorded at 2½-minute intervals: Grazing, cudding,

idling, and resting. It should be noted that, at this stage of the experiment, one member of each of the nine sets of twins initially treated was still being injected daily, the number of sets being reduced to six at a later date.

Intake Measurement

The consumption of cut grass fed *ab lib.* to six sets of twins under stall-feeding conditions was measured throughout one week in January 1952, otherwise the animals had free access to good pasture supplemented by hay and silage during the summer and winter months.

Milk Yield

As from the day following calving, the animals were brought into the milking herd where they were subjected to a standardized milking procedure of twice-daily milking. Milk yields were recorded for each milking and a composite morning and evening sample tested daily for fat content.

RESULTS

Growth

The period of growth under consideration may be conveniently divided into four major periods, i.e.:

1. The six months during which the injections were administered.
2. The three months lapsing between the last injection and calving.
3. The lactation period.
4. The dry period between the end of lactation and the following calving. (This period was not uniform between animals because of a marked variation in the subsequent calving dates of the animals involved.)

Body weights and measurements presented in the tables, or shown diagrammatically, were obtained by taking five-weekly moving averages of the weekly measurements.

The growth comparisons in the case of Twins 289, 290 and 293, 294 were complicated by some difference in calving date within sets, but in general their behaviour was essentially similar to that of the other four sets.

Weight: In all six pairs it was apparent that the thyroxin injections led to a considerably diminished rate of gain, this divergence being accentuated in the latter three months of the injection period.

Following the cessation of injections, the treated animal of each pair gained weight at a more rapid rate than its twin. In consequence, the weight difference at the time of calving was negligible.

Following calving, the thyroxin-treated animals gained weight more rapidly than their mates, the weight difference diminishing as lactation advanced.

Throughout the dry period the weight differences within twin sets decreased further (Fig. 1).

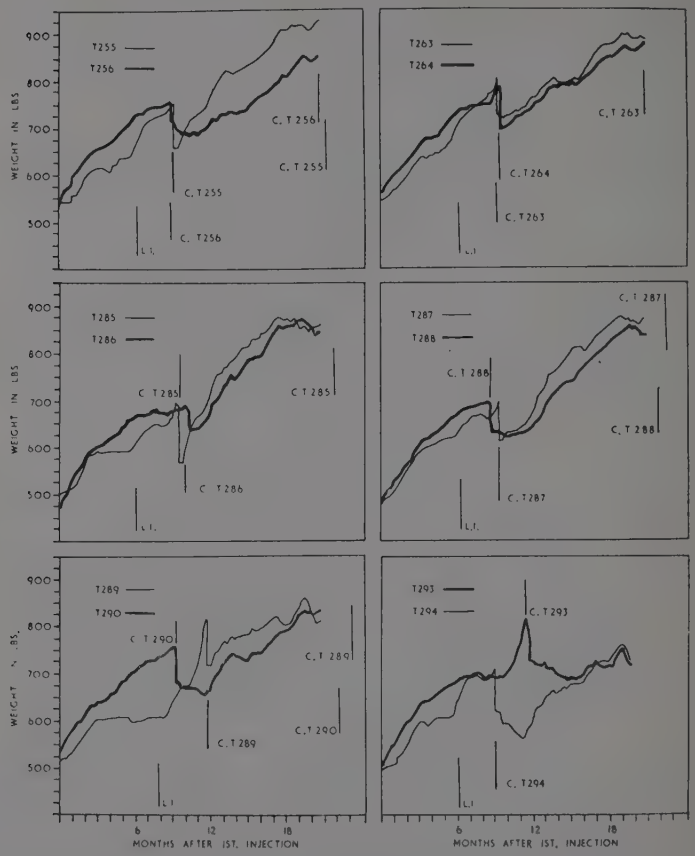

Fig. 1.—Liveweight gain.

L.I. last injection. **C.** calving date. —treated animal. —control animal.

Chest Girth: During the thyroxin injection period the chest girth of the treated animals increased at a lesser rate than that of the control animals. In the winter months that followed the cessation of injections, all animals lost condition, as measured by chest girth, this being due to a general seasonal feed shortage. This decline in chest girth continued throughout the calving period, being followed by a marked increase once the spring flush of grass set in. This rate of increase is apparently somewhat greater in the case of the thyroxin animals than in the controls (Fig. 2). Thereafter, the chest girth of the two groups was similar.

Belly Girth: A very sudden drop in belly girth following the commencement of thyroxin injections characterized the injected animals. Thereafter, throughout the injection period, they lagged behind their

twin mates in this measurement. With the cessation of injections they rapidly approached the belly girth size of their mates, while after the onset of the winter pasture shortage they tended to diminish less in this measurement than their mates. Consequently, at the time of calving there was no characteristic difference between the two groups in respect to belly girth. Following calving, the increase in belly girth was similar in both groups (Fig. 3).

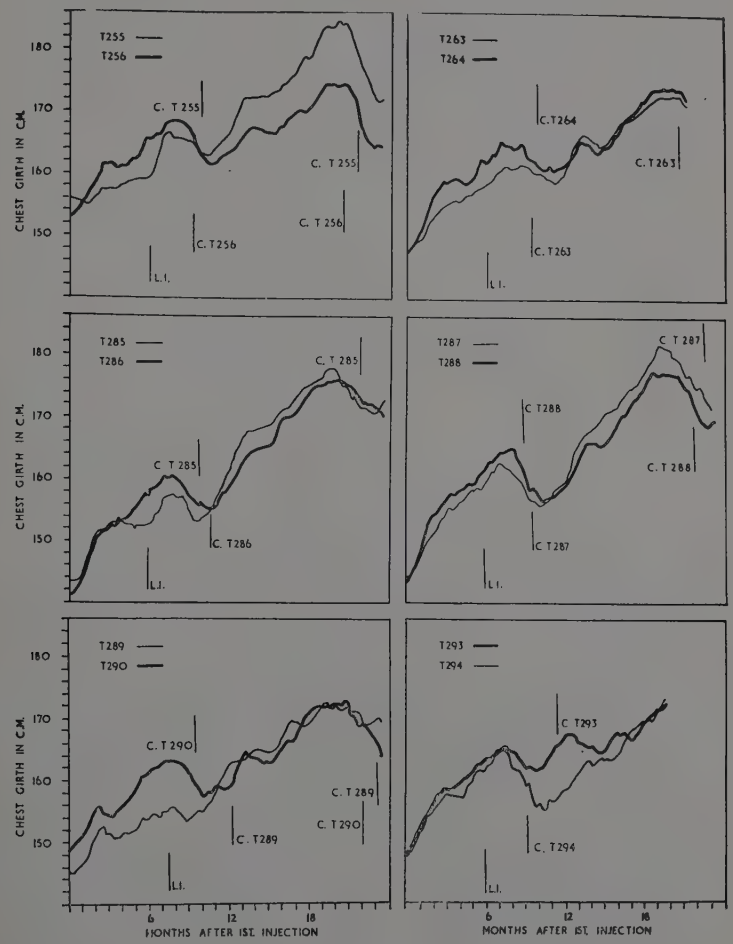

Fig. 2.—Chest girth.

Height Over Withers: The thyroxin-treated animals increased in height throughout the injection period more than did the controls. Once injections ceased, this difference tended to diminish slowly throughout the pre-calving and lactation periods. Considerable variation in what

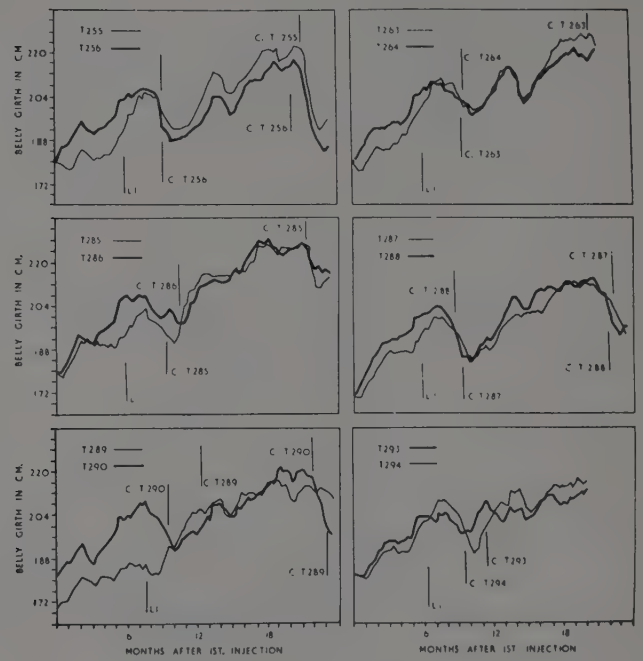

Fig. 3.—Belly girth.

may be considered the genotype–treatment interaction is apparent in this measurement, for some animals increased in height much more than others, while Twin No. 294 increased more slowly in height than her untreated mate (Fig. 4).

Hip–hip: Throughout the injection period there appeared to be a tendency for the thyroxin animals to increase at a slightly greater rate than the controls. With the onset of spring flush of grass, however, the difference between the two groups became greater, the treated animals in five cases out of six showing a greater increase (Fig. 5). Thereafter, the difference between twins diminished in most sets.

Hip-pin: Throughout the injection period the treated animals showed an increased rate of gain compared with their mates. During the three months preceding calving, the difference established earlier was maintained, and again increased following the spring flush of grass. At the end of lactation the differences tended to become equated (Fig. 6.).

Heart Rate

The effect of thyroxin on the number of heart beats per minute was most marked. Because of the initial large differences recorded in heart rates within twin sets, the dosage of thyroxin was reduced in two stages from a level of 0.5 mg./100 lb. live weight to 0.4 mg./100 lb. live

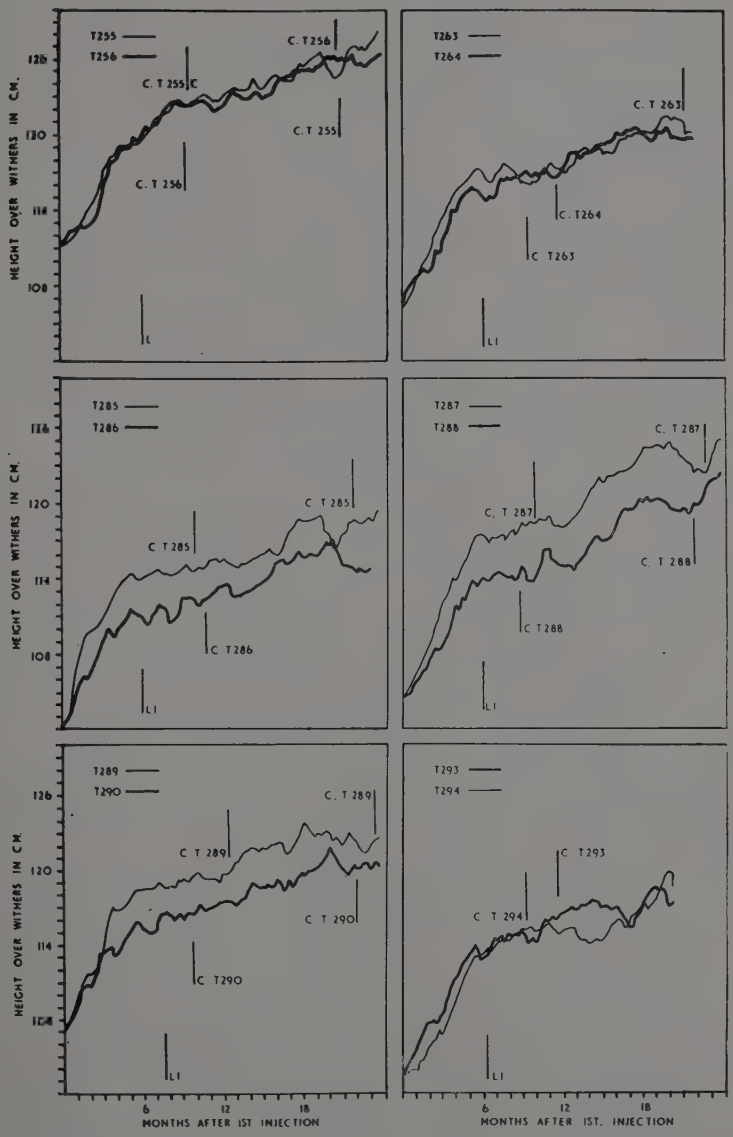

Fig. 4.—Height over withers.

weight, this latter dosage maintaining a hyperthyroid state. With the cessation of thyroxin injections, the heart rates of the treated animals dropped rapidly, falling below that recorded for the controls in all cases.

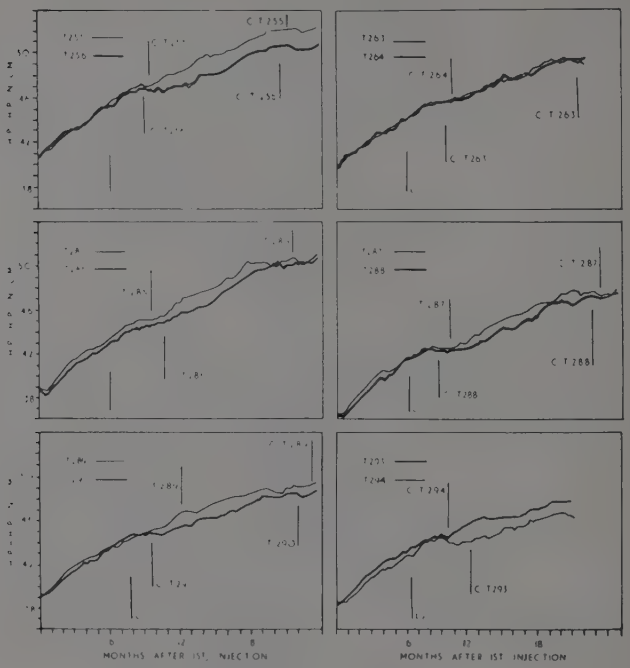

Fig. 5.—Hip to hip.

The percentage difference in heart rate on a mean monthly basis between the members of twin sets is presented in Table 2.

TABLE 2. HEART RATE

Differences within sets expressed as a percentage of the heart rate of the control animal (four-weekly average)

Twin Pair	MONTHS						
	Therapy Period						Post Therapy
	1	2	3	4	5	6	7
255–256	14.8	15.5	19.6	22.9	19.2	16.9	−16.7
263–264	33.8	27.6	14.6	21.1	27.1	25.4	− 5.6
285–286	6.6	11.0	20.7	19.8	22.9	15.7	− 7.4
287–288	4.6	13.1	3.8	12.2	18.1	18.0	−13.6
289–290	25.8	20.5	21.8	20.2	28.2	10.7	−10.1
293–294	23.4	11.4	20.9	42.1	62.0	49.7	−20.1

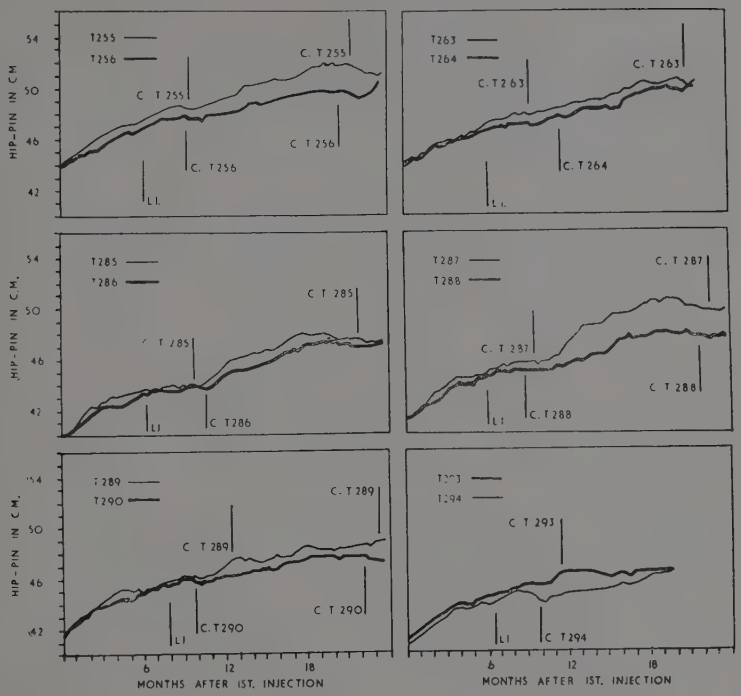

Fig. 6.—Hip to pin.

TABLE 3. GRAZING BEHAVIOUR RESULTS
Expressed in Minutes as a Daily Average

Cow	Grazing Time	Cudding Time	Idling Time	Resting Time
Treated				
255	459	500	195	286
262	359	446	243	392
263	368	499	242	331
277	396	516	230	308
285	478	491	142	329
287	424	512	140	364
289	397	528	172	343
292	453	557	140	290
294	451	499	185	305
Control				
256	477	482	179	302
261	418	451	206	365
264	397	476	230	337
278	406	491	194	349
286	495	477	182	286
288	428	480	197	295
290	405	461	189	235
291	513	521	131	235
293	492	542	163	234

Grazing Behaviour

Table 3 sets out the average daily duration of the grazing, cudding, idling, and resting periods recorded for the nine sets of twins throughout the four 24-hour periods during which they were watched. The result of an analysis of variance of grazing time and cudding time is presented in Table 4.

TABLE 4. ANALYSIS OF VARIANCE OF GRAZING BEHAVIOUR

Source of Variation	df.	Grazing Time (min.) M.S.	Cudding Time (min.) M.S.
Sets	8	15,174(1)	5,221(1)
Days	3	16,896(1)	76,457(1)
Treatments	1	13,862(1)	6,197(2)
Sets × Days	23	819	1,643
Days × Treatments	3	694	2,183
Sets × Treatments	8	898	1,795
Sets × Days × Treatments	23	690	1,056
Total	69		

(1) P.0.01 (2) P.0.05

Grazing Time: The variance ratio betwen sets, between days, and between treatments is in each case highly significant ($P = 0.01$). There is no evidence, however, of any interaction between days, treatments, and sets. The mean daily grazing time for the thyroxin animals was 419.7 minutes, compared with 447.4 minutes for the control group, the difference being 27.7 minutes.

Cudding Time: Again the greater part of the variation encountered could be attributed to sets, to days, and to the treatment. The interactions between these variates was in each case non-significant. The cudding time of the thyroxin animals, in contrast to grazing time, was appreciably greater than that of the control animals, the respective means being 502.4 and 483.9 minutes.

The shorter grazing times and longer cudding time of the thyroxin animals appeared to be something of an anomaly, for Hancock[5] has demonstrated that the greater the intake of an animal the greater is the duration of the cudding time. The disparity in grazing time could only be explained, therefore, by the hypothesis that the thyroxin animals grazed at an appreciably faster rate, and thus consumed more pasture in a shorter time than their mates. This hypothesis was tested by measuring the consumption of freshly cut pasture fed *ad lib.* under stall feeding conditions to six sets of the twins involved. During one 24-hour period of this week the total eating time and cudding time for each animal was recorded (Table 5).

TABLE 5. ACTUAL INTAKE, EATING TIME, AND CUDDING TIME
(Under Stall Feeding Conditions)

Set	Intake (lb./day, average of 7 days)		Eating Time (Min./day)		Cudding Time (Min./day)	
	Thyroxin	Control	Thyroxin	Control	Thyroxin	Control
255–256	79.7	69.9	97.5	103.0	374	377
261–262	71.4	58.1	102.8	78.3	337	279
263–264	83.8	81.5	111.1	112.4	428	434
285–286	63.7	69.8	102.6	105.8	422	396
289–290	75.8	55.2	111.7	78.2	485	287
291–292	76.5	59.7	107.4	91.3	385	278
	450.9	394.1	633.1	569.0	2,431	2,051

Intake

The average daily intake of grass recorded in pounds of fresh material actually consumed by the six sets of animals in seven consecutive days is recorded in Table 5. In the same table the figures recorded

TABLE 6. MILK PRODUCTION DATA

Twin No.	Treatment	Yield 3 Months				Total Yield				Days in Milk
		Milk lb.	Fat lb.	Fat %	FCM lb.	Milk lb.	Fat lb.	Fat %	FCM lb.	
255	Thyroxin	1386	54	3.95	1364	4213	188	4.45	4505	285
256	Control	2208	89	4.04	2218	6997	308	5.45	7419	305
263	Thyroxin	1489	67	4.5	1607	4755	247	5.2	5607	305
264	Control	1624	68	4.17	1670	4923	240	4.87	5569	305
285	Thyroxin	467	19	4.16	472	487	20	4.12	495	96
286	Control	1157	51	4.43	1228	2401	115	4.75	2685	222
287	Thyroxin	592	25	4.22	612	919	41	4.45	983	187
288	Control	1449	62	3.25	1510	3059	137	4.48	3279	255
289	Thyroxin	2212	85	3.84	2160	5542	234	4.20	5727	252
290	Control	1919	73	3.82	1863	5301	216	4.07	5360	252
294	Thyroxin	1561	66	4.22	1614	5416	274	5.06	6276	305
293	Control	2486	103	4.23	2530	5423	255	4.70	5994	252
Average	Thyroxin	1285	52.7	4.15	1305	3555	167	4.58	3932	238
	Control	1807	74.3	3.99	1836	4683	212	4.72	5051	265

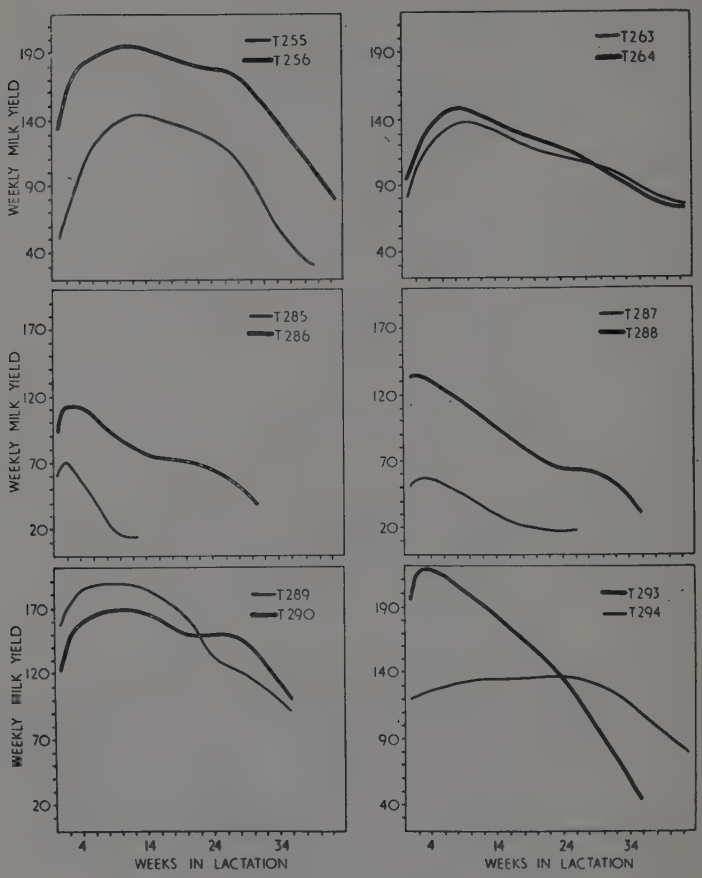

Fig. 7.—Weekly milk yield.

for cudding time and actual eating time, for these same animals when watched throughout a 24-hour period, are presented.

An analysis of variance of these data, together with a one-tailed t test demonstrated significant differences between the two groups in both total intake and cudding time; however, no difference in eating time was discernible. Thus, the hypothesis that the hyperthyroid animals consumed more feed per unit time than the control animals was confirmed.

Milk Yield

Details of the production performance of each animal during the lactation following the treatment period are outlined in Table 6.

An analysis of variance of the yield of 4% milk indicated a significant difference between the production of the two groups at three

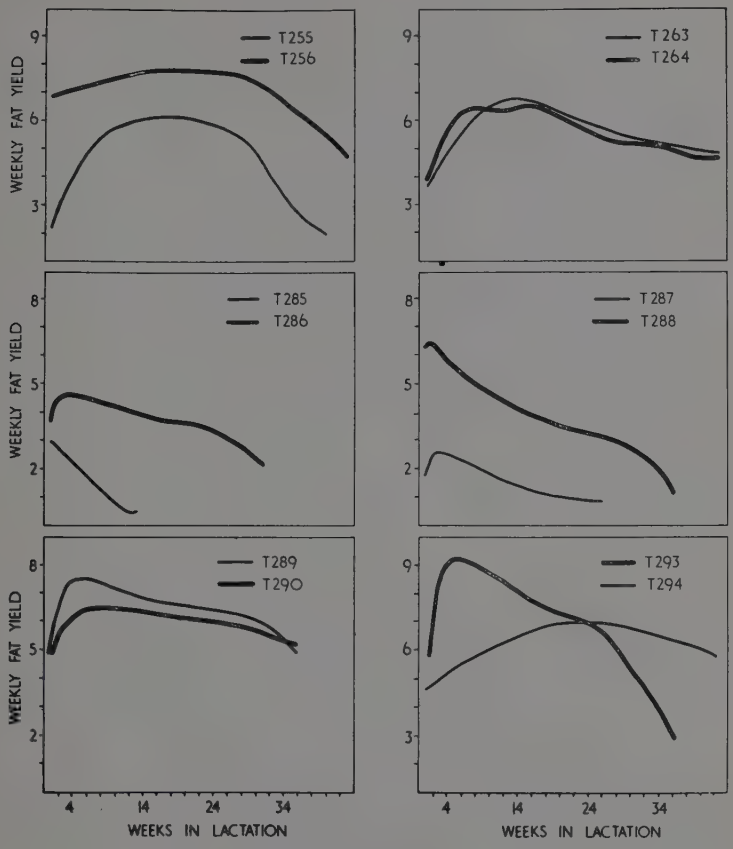

Fig. 8.—Weekly fat yield.

months but not at the end of lactation, the treated group being the lower in production. However, there was no significant difference in the duration of lactation between the treated and non-treated twins, nor in the fat test of either group. The lactation curve of both the fat and milk yield of each animal is presented in Figs. 7 and 8.

As with several of the body measurements, it is apparent that in terms of milk production some animals reacted with much less tolerance to the administration of thyroxin than others. No apparent relationship between the growth and lactational response could be detected, nor did there appear to be any relation to the extent of the hyperthyroid state as measured by heart rate.

DISCUSSION

In spite of a wide interest in the potentialities of thyroid-active materials as a means of augmenting established lactation, few reports

have appeared indicating the influence of such substances upon body growth. The only extensive study as far as the authors are aware, is that carried out by Dryendahl who in a recent publication[3] reported that the administration of iodinated casein to growing cattle resulted in an increase in weight and in both body height and length, there being, however, a loss of body fat. The growth studies recorded in this paper have indicated that a hyperthroid state of the order reported augments skeletal growth whilst depressing the increment in those measures that reflect body condition. In this connection it is worth noting that chest girth proved to be as sensitive a measure of body condition as body weight. The rapid drop in belly girth associated with the commencement of thyroid therapy is an interesting observation, especially in view of the increase in feed consumption and the probable increase in water intake[6]. The reason for the decline, however, is not understood. The depression of normal thyroid activity induced during the period of thyroxin injection, is reflected in the weight gain of the thyroid animals once injections ceased, this increased gain continuing throughout the early lactation period. The height of the animals, as recorded over the withers, proved to be the most sensitive skeletal measurement; hip pin and hip-hip measurements were much slower in showing differences and more persistent in retaining these differences once therapy ceased. All differences, however, tended to become equated as the animals matured.

Of particular interest is the increase in feed consumption under free grazing conditions, this being accomplished, moreover, in a shorter grazing period. In spite of an increased consumption of pasture, the weight increase of the hyperthyroid twins was less than that of their mates, even though bone growth was greater. It would appear, therefore, that the general efficiency of the growth process has been impaired. Such a situation is not suprising, for Moustgaard and Thorbeck[7] have demonstrated an increased heat production in hyperthyroid animals.

Of the six sets of twins employed in this experiment the members of two sets differed appreciably in calving date. This situation unfortunately complicated the interpretation of the milk and fat production results of these two sets, for in New Zealand the peak phase of a cow's lactation is usually timed to coincide with the period of maximum pasture growth. Thus early-calving cattle tend to be underfed for the first few weeks of lactation while cattle calving later are much better fed in the early phase of lactation but tend to have a shorter lactation period. In this way the lactation curves of identical twin cattle may be caused to differ appreciably. For this reason then any interpretation of the lactation records of twin sets 289-290 and 293-294 must be viewed with caution. Of the remaining four sets, the thyroxin-treated members produced appreciably less in three cases and about the same in the fourth case. Rather than aiding potential mammary development then, it would appear that a state of hyperthyroidism of this order depresses the subsequent lactation yield. Whether or not this is largely due to a mammary growth effect or to the interference of the endogenous endocrine balance remains to be determined. One of us (C.W.T.) has frequently stressed that the dosage level of hormone therapy is highly critical and in consequence is of the opinion that a hyperthyroid state of lesser magnitude may lead to a somewhat different end result from the one reported herein.

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EFFECTS OF DEFOLIATION AND SHADING ON SHORT-ROTATION RYEGRASS

By K. J. Mitchell and S. T. J. Coles, Grasslands Division, Department of Scientific and Industrial Research, Palmerston North

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Summary

Defoliation, and the shading of either the whole plant or only the base of it, were compared, in an attempt to gain understanding of the effect of different types of grazing management on the field performance of short-rotation ryegrass.

In full light, repeated defoliation checked tillering a little, but drastically reduced the quantity of tissue formed by individual tillers, largely through reduction in the size of the leaves being formed. That effect persisted for several weeks after defoliation ceased. The more severe the defoliation the more pronounced were the above effects. Four defoliations at 6-day intervals reduced the quantity of tissue formed to an eighth, compared with undefoliated plants.

Base shading and general shading reduced both tillering and rate of tissue formation on a tiller. When base-shaded plants were defoliated and then placed in full light, tillering became more rapid than on plants remaining base-shaded but not defoliated. The reduction in weight of tissue formed by a tiller of base-shaded plants, when defoliated, was relatively small if the plants were then put in full light.

Introduction

The morphology of growth of ryegrass, growing both as individual plants in pots[1, 5, 6] and in pastures given different grazing management has been examined (K. J. Mitchell, unpublished studies). It is apparent that in most pastures the individual tiller of ryegrass is the growth unit. Each tiller is capable of establishing its own root system, and producing tillers from the axils of its leaves. It can continue producing leaves from its meristematic apex as long as it remains in the vegetative phase of growth. There is little morphological difference between a vegetative tiller in a pasture 20 years old and a tiller on a plant only a few weeks old.

The rate of growth of ryegrass, or other morphologically similar species, is determined by the rate of production of tillers, the rate at which leaves are produced on the tillers, and the dimensions attained by the leaves. Consequently, a detailed examination of the effect of suitably chosen treatments on tiller development of individual plants with a form of growth reasonably comparable with that met in a pasture should advance the understanding of the performance of species under various pasture management conditions.

Short-rotation ryegrass is a pasture strain produced to combine high winter production with relative permanence in a pasture. Published information concerning its response to different types of pasture management is limited. It was early found that continued close grazing, often encouraged by its palatability, was detrimental[3]. On dairy farms the rapid winter growth after an autumn seeding is liable to smother clover seedlings[7]. Brougham[1] has shown that there is considerable flexibility in methods of controlling this by adjusting grazing times or seeding rates.

EXPERIMENTAL PROCEDURE

Two separate experiments were carried out. In the first, there was a comparison of various defoliation and shading procedures. In the second, the treatments were chosen to be more directly comparable with various sets of pasture conditions. A schedule of the shading and defoliation procedures used in each experiment is set out in Tables 1 and 2. For both experiments the time at which treatments commenced or were changed is stated in terms of number of days from the emergence of the seedlings.

TABLE 1. EXPERIMENT 1—DESCRIPTION OF TREATMENTS

	Up to 39th day from seedling emergence	On 39th day	After 39th day
1	Full light—Undefoliated	Nil	Full light
2	,, ,, ,,	Defoliated to 4 cm.	,, ,,
3	Full light—Defoliated to 4 cm. on 27th and 33rd day	,, ,, ,, ,,	,, ,,
4	General shading—Undefoliated	Nil	General shading
5	,, ,, ,,	Transferred to full light—Undefoliated	Full light
6	,, ,, ,,	Defoliated to 4 cm. then transferred to full light	,, ,,
7	,, ,, ,,	Defoliated to 4 cm.	General shading
8	Base shaded ,,	Nil	Base shaded
9	,, ,, ,,	Transferred to full light	Full light
10	,, ,, ,,	Defoliated to 4 cm. then transferred to full light	,, ,,
11	,, ,, ,,	Defoliated to 4 cm. then transferred to general shading	General shading

Plants were grown in three-quart glazed earthenware pots, containing highly fertile potting soil. There were three plants per pot in the first experiment and one per pot in the second, but in each case 15 plants per treatment. The procedure for observations during growth and for harvesting was the same as in previous experiments[7].

Seed was sown in March, and treatments commenced in early April. Plants were harvested in May or early June. A glasshouse, heated during the latter part of each experiment, was used. This gave mean temperatures about 5°F. above those outside, but a 35% reduction in light intensity.

In the second experiment a supplementary group of plants (Series B, Table 2) undefoliated and in full light was used. Seed for these plants was sown a month after the main group. This gave a comparison with other treatments, which continued after the initial group of plants, undefoliated and in full light, had been harvested.

TABLE 2. EXPERIMENT 2—DESCRIPTION OF TREATMENTS

	Treatment	Number of days from emergence						
		1st Defoliation	2nd Defoliation	3rd Defoliation	4th Defoliation			Final Harvest
1	Full light—Undefoliated	—	—	—	—			62
2	" —Defoliated 4 times to 8 cm.	23	29	35	41			65
3	" " — " " " 4 cm.	"	"	"	"			69
4	" " — " " " 2 cm.	"	"	"	"			72
5	" —Undefoliated—Series B	—	—	—	—			69
		Shades Put On	Defoliated and Shades Removed	Shades Replaced	Height of Shades Increased			Final Harvest
6	Base shaded—Undefoliated	23	—	—	—			76
7	" —Defoliated once to 8 cm.	"	41	51	58 & 65			84
8	" " — " " 4 cm.	"	"	58	65 & 74			97
9	" " — " " 2 cm.	"	"	65	74 & 85			97

In the "general shading" treatments, plants were placed under a hood of two layers of loosely woven scrim, which reduced the incidence of light by 70%.

In the "base-shaded" treatments the total quantity of light received by the plant as a whole was also reduced by 70%. This was achieved by

wrapping layers of green butter-muslin round a wire frame surrounding each plant and adjusting the height and density of the muslin wrapping as required (Fig. 1). To give the gradation from slight shading at the top to denser shading near the soil surface, there was only a single layer of muslin at the top with an increase to several layers around the base of the shade. The height of the base shade was increased as the plants grew taller. In the first experiment this was adjusted for each plant individually but, in the second, shades were set to the same level for all plants in each group. This is comparable with the situation in a long pasture where the degree of shading received by individual plants is determined by the height of the pasture as a whole. If a tiller is short it receives a less than average quantity of light.

Fig. 1.—Base-shaded plants after defoliation to 4 cm. As the plants grew, the shading was gradually raised to the full height of the frame (23 cm.).

The base shades were removed at defoliation, then in the second trial replaced when regrowth was up to 10 to 12 cm, the height and density of shading being gradually increased. The aim was to duplicate the gradual re-introduction of shading around the base of the plant as regrowth occurs in a pasture.

Conclusions based on differences in tested data are drawn only where the test used indicates significance at least at the 5% level of probability. Standard errors are quoted on directly measured data, and co-efficients of variation where results are an extrapolation forward or backward of directly measured data. For other data only major differences are noted.

Results

Experiment 1—Autumn 1953

Results from the first experiment are presented briefly, for many of the conclusions were amplified by the second experiment in the following year.

Growth of Whole Plant

Since the effect of different shading procedures on rate of growth was being studied, all treatments were harvested concurrently. Differences in dry weight per plant are therefore attributable to the treatments used (Table 3). The main points of interest are:

1. Undefoliated plants in full light formed an average of 5160 mg. of shoot tissue in the 81 days from emergence to harvest. A single defoliation to a height of 4 cm. half way through the growth period (day 39) reduced the final yield to 40% and three defoliations (days 27, 33 & 39) reduced it to less than 25%.
2. The mean weight of shoot was similar for the groups receiving base shading and general shading treatments.
3. With plants shaded up to the 39th day and then transferred to full light, the final shoot weight was no greater than that of plants in full light that were defoliated on the 39th day, despite the higher weight and much greater area of leaf tissue present on the shaded plants when transferred to full light.
4. The relative reduction in total shoot growth following defoliation was the same irrespective of whether the plants were initially in full light or shaded. Final weight of the shoot was reduced to approximately 40%.

Table 3 also shows the weight of leaf tissue removed at the defoliation on day 39, and the mean leaf area remaining. Plants defoliated three times had an average of 4.27 sq. cm. of leaf surface remaining on day 39 and plants previously shaded an average 0.45 sq. cm. At harvest there was only a 20% difference in mean shoot weight of the two groups. Again, plants continually in full light and defoliated once had only half as much leaf tissue remaining as plants defoliated three times, yet finally had double the shoot weight.

TABLE 3. EXPERIMENT 1– PLANT WEIGHTS AND PROPORTIONS AT HARVEST, WEIGHT OF TISSUE REMOVED, AND LEAF AREA REMAINING AT DAY 39

	Treatment*	Mean Weight at Harvest (mg. D.M.)			Dry Matter Percentage	Root : Shoot Ratio	Defoliation	
		Shoot	Root	Total Plant			Weight of tissue removed (mg.)	Area of leaf blade remaining (sq. cm.)
		S.E.			S.E.	S.E.		
1	Full light—Undefoliated	5160 ±370	1290	6450	14.2 ±0.4	0.25 ±0.02		
2	,, ,, —Defoliated once	2200 ±250	—	—	13.1 ±0.2	—	899	2.69
3	,, ,, — ,, three times	1170 ±110	240	1310	12.5 ±0.2	0.20 ±0.02	†	4.27
4	General shading—Undefoliated—Continues general shading	650 ± 60	70	720	10.7 ±0.3	0.11 ±0.02		
5	,, ,, - ,, —Then full light	2110 ±240	750	2860	13.7 ±0.4	0.34 ±0.06		
6	,, ,, — Defoliated — ,, ,, ,,	930 ± 90	160	1090	11.6 ±0.4	0.17 ±0.01	328	0.49
7	,, ,, — ,, —Continues general shading	170 ± 10	20	190	11.6 ±0.3	0.12 ±0.03	302	0.52
8	Base shading— Undefoliated—Continues base shading	580 ± 30	70	650	12.7 ±0.3	0.11 ±0.01		
9	,, ,, — ,, —Then full light	2150 ±310	780	2930	13.8 ±0.4	0.38 ±0.05		
10	,, ,, — Defoliated — ,, ,, ,,	880 ± 40	160	1040	13.5 ±0.3	0.17 ±0.01	309	0.41
11	,, ,, — ,, —Then general shading	120 ± 10	20	140	11.8 ±0.2	0.12 ±0.01	308	0.46

* described in more detail in Table 1.

† not recorded.

Tillering

Previous experiments have shown that tillering of ryegrass plants grown in full light can be temporarily checked by a single defoliation and more so if defoliation is repeated[7]. That is confirmed by the results of this experiment (Fig. 2).

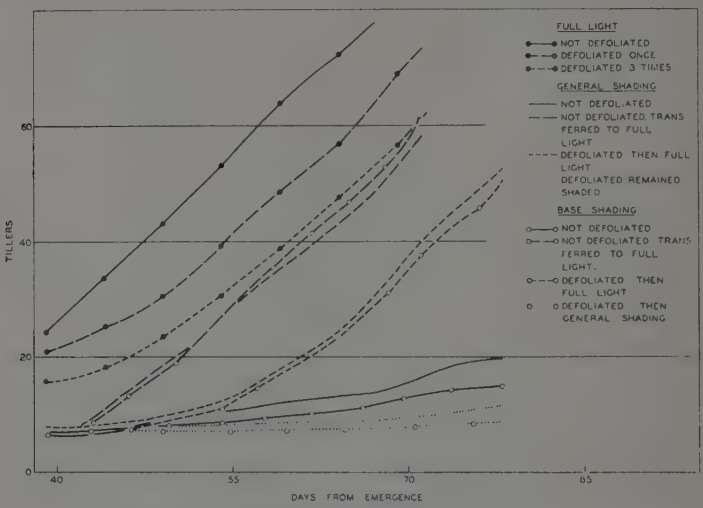

Fig. 2.—Increase in tiller numbers—Experiment 1.

If shaded plants were transferred to full light without defoliation there was an immediate increase in tillering, which continued at a rate equal to that of plants which were always in full light (Fig. 2). Where shaded plants were defoliated, when transferred to full light the increase in rate of tillering was delayed for about 10 days but, once it commenced, tiller numbers increased equally fast. Consequently, at the end of the trial these defoliated plants had about four times as many tillers as plants that were never defoliated but remained shaded.

The similarity in tiller numbers on plants given base shading or general shading indicates that the number of tillers formed by shaded plants is determined by the total quantity of light energy available for photosynthesis rather than by the light intensity at the base of the plant.

Leaf Dimensions

As rate of leaf appearance on the primary tiller was so altered by treatments, comparisons of leaves at the same position on the main stem are not appropriate. Table 1 records leaf dimensions for the final position on the primary tiller where leaves on all plants in a treatment had matured.

On undefoliated plants shading produced leaf blades that were longer, but of lower dry matter. Defoliation reduced leaf dimensions, and the relative effect was greater in continually shaded plants.

TABLE 4. EXPERIMENT 1—RATE OF APPEARANCE OF SUCCESSIVE LEAVES ON MAIN STEM AND DIMENSIONS OF REPRESENTATIVE LEAVES

Dimensions are for the last leaf position in each treatment at which all leaves were mature

	Treatment*	Average number of leaves appearing on main stem per week in period after final treatments commenced i.e. after day 39	Dimensions of Leaf Blade					Total quantity of tissue formed on main stem in 20 days after final treatments commenced (mg.)
			Length (cm.)	Width (cm.)	Area (sq. cm.)	Dry Weight (mg.)	Dry Weight per sq. cm. (mg.)	
			S.E.	S.E.				
1	Full light—Undefoliated	0.79	20.5 ±1.0	0.51 ±0.02	10.9	21.0	1.93	89.4
2	„ „ —Defoliated once	0.79	15.0 ±0.9	0.45 ±0.02	6.4	11.7	1.83	38.0
3	„ „ — „ three times	0.86	13.9 ±0.9	0.38 ±0.01	5.0	8.4	1.68	21.2
4	General shading—Undefoliated Continues general shading	0.66	26.1 ±0.8	0.50 ±0.02	12.4	14.6	1.18	47.8
5	„ „ — „ —Then full light	0.91	18.9 ±0.6	0.53 ±0.03	9.5	17.7	1.86	86.6
6	„ „ — Defoliated — „ „ „	0.84	14.0 ±0.7	0.45 ±0.03	6.0	10.2	1.70	31.6
7	„ „ — „ —Continues general shading	0.48	15.7 ±0.7	0.38 ±0.02	5.7	6.5	1.14	13.8
8	Base shading—Undefoliated—Continues base shading	0.63	26.9 ±1.5	0.45 ±0.02	11.5	16.8	1.46	53.6
9	„ „ — „ —Then full light	0.98	17.5 ±1.4	0.55 ±0.03	9.2	16.1	1.75	85.6
10	„ „ — Defoliated — „ „ „	0.88	11.7 ±0.7	0.41 ±0.01	4.6	8.4	1.83	27.4
11	„ „ — „ —Then general shading	0.57	15.2 ±0.6	0.38 ±0.02	5.5	6.3	1.15	12.3

*described in more detail in Table 1.

Base shading did not result in larger leaves than did equivalent general shading.

Tissue Formation on a Single Tiller

The estimated weight of tissue formed by the primary tiller in the 20 days after final treatments commenced is given in Table 4. The primary tiller of intact plants in full light formed between 85 and 90 mg. of tissue. Where plants were shaded but not defoliated the tiller formed between 48 and 54 mg., and, where plants were defoliated, less than 40 mg.

Where plants were both defoliated and shaded, tissue formation dropped to about a seventh of that in full light.

Experiment 2—Autumn 1954

Plant Weight and Proportions

As the emphasis in this experiment was on the course of tillering and the growth of individual tillers, the groups of plants were harvested, not at equal number of days from emergence, but when a similar number of leaves had appeared on the primary tiller. Consequently comparisons of plant weights do not give a direct indication of rate of growth.

With increasing severity of defoliation there was a progressive reduction in quantity of shoot tissue formed by plants in full light (Table 5). At the first defoliation, most tissue was removed from the plants cut at 2 cm., but, by the fourth defoliation, five times more tissue was removed from plants cut at 8 cm. than from those cut at 2 cm.

Where plants were growing in full light, increasing severity of defoliation gave, even after 20 to 30 days of free growth, a higher proportion of leaf blade to leaf sheath, but a lower proportion of root tissue to shoot tissue, a major reduction in weight per tiller, and a lower dry-matter percentage of the leaf blades and sheaths.

In the base-shaded treatments the root was about 10% of the mean dry weight of the shoot, weight per tiller was higher than with plants in full light defoliated to comparable heights, and dry matter percentage was again reduced by defoliation.

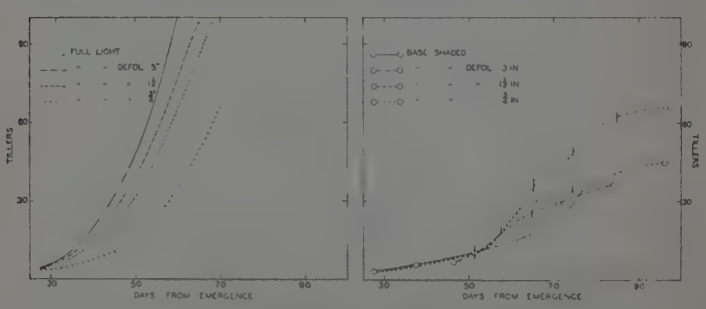

Fig. 3.—Increase in tiller numbers.—Experiment 2. For the base-shaded group, dates at which shades were increased in height and date of defoliation are marked by vertical lines.

TABLE 5. EXPERIMENT 2—PLANT WEIGHT AND PROPORTIONS AT FINAL HARVEST

Treatment	Days from Emergence	Total Weight of Shoot (mg.D.M.)	Ratio of Leaf Blades to Leaf Sheaths	Ratio Shoot to Root	Weight per Tiller (mg. D.M.)	Dry Matter Percentage		
						Leaf Blades	Leaf Sheaths	Total Shoot
		S.E.	S.E.					S.E.
Full Light								
Undefoliated	62	7550±340	1.99 ±0.06	0.26	69.3	13.2	13.2	13.2 ±0.3
Defoliated at 8 cm.	65	5010±350	1.97 ±0.07	0.20	51.3	12.1	11.6	11.9 ±0.4
,, ,, 4 cm.	69	3630±280	2.16 ±0.09	0.17	36.8	12.0	11.4	11.9 ±0.2
,, ,, 2 cm.	72	1430±120	2.24 ±0.10	0.10	19.0	11.7	10.5	11.4 ±0.2
Undefoliated—Series B	69	7750±390			70.6			12.5 ±0.2
Base Shaded								
Undefoliated	76	1870±300	2.57 ±0.16	0.11	59.6	12.9	11.1	12.5 ±0.2
Defoliated at 8 cm.	84	2200±510	2.98 ±0.17	0.08	60.7	12.3	10.2	11.6 ±0.2
,, ,, 4 cm.	97	3710±450	2.00 ±0.09	0.09	82.0	11.3	10.2	10.9 ±0.2
,, ,, 2 cm.	97	3240±390	2.43 ±0.17	0.12	49.4	10.2	9.2	10.0 ±0.2

No regular trends in plant proportions are apparent from comparisons between base-shaded treatments. With the interaction between changing light levels and defoliation, and with the difficulty of ensuring comparable gradation in re-introduction of shading as regrowth occurs, this is not unexpected.

Tillering

For plants in full light, tillering was progressively checked by increasing severity of defoliation (Fig. 3). Mean tiller numbers per plant on day 49 (i.e. ten days after the last defoliation) were 51, 41, 33, and 16 for plants undefoliated or defoliated to 8 cm., 4 cm., and 2 cm. respectively.

The rate of formation of tillers was considerably less when plants were continually base-shaded but not defoliated. Defoliation of the base-shaded plants caused at first a slight check to tiller initiation but, as it also brought the plants into full light, rate of tillering soon increased to a level above that of plants which were not defoliated but remained base-shaded.

With each of the defoliated groups, shading was re-introduced in three stages, which are marked in Fig. 3. Each increase in shading gave an immediate check to increase in tiller number. As shading of plants defoliated to 8 cm. was re-introduced earliest, their final tiller number was least.

Rate of Appearance of Leaves on Primary Tiller

This was reduced by shading or severe defoliation (Fig. 4). In the 14 days after the final defoliations, undefoliated plants in full light formed an average of 2.2 leaves, but plants base-shaded and then defoliated to 2 cm. formed only 1.3 leaves.

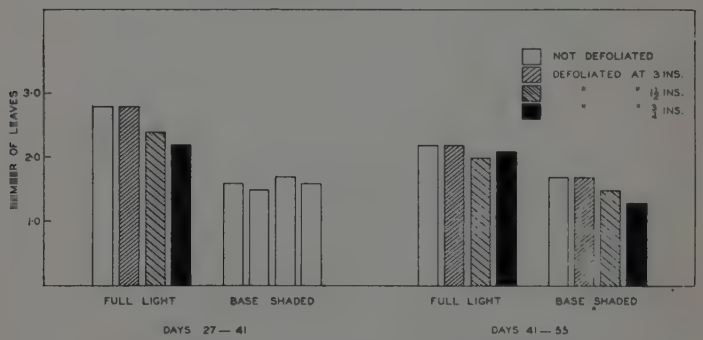

Fig. 4.—Mean increase in number of leaves on primary tiller in two 14-day periods. Plants in full light were being defoliated in the first period only. The base-shaded group had uniform shading without defoliation in the first period, and were defoliated at the end of it. Leaf appearance in the second period reflects the effect of that single defoliation.

Dimensions of Leaf Blades

Trends for both length and width of leaf blade of successive leaves on the main stem are set out in Fig. 5. In all treatments there was a trend for length of successive leaf blades to increase, and there was no indication of a maximum having been reached. After defoliation there was a reduction in length of blades of leaves being formed. This

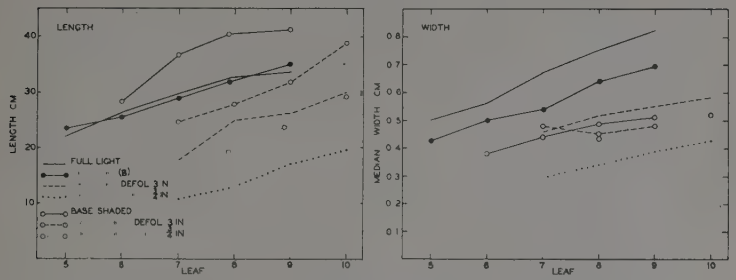

Fig. 5.—Length and median width of blade of successive leaves on primary tiller.

reduction increased with increasing severity of defoliation. However, irrespective of degree of previous defoliation, and hence length of leaf blade, the increase in length between successive leaves remained approximately 3 cm.

There was a large increase in width of successive leaves on undefoliated plants in full light. With plants growing in full light, several defoliations caused a reduction in leaf width, which also increased with the severity of defoliation. However, where plants were previously base-shaded the single defoliation had little effect on leaf width irrespective of its severity. The increment in width between successive leaves of plants defoliated or base shaded is no greater, and generally less, than that on plants given free growth in full light.

TABLE 6. DIMENSIONS OF BLADE OF NINTH LEAF ON PRIMARY TILLER

Treatment	Length (cm.)	Width (cm.)	Area (sq. cm.)	Dry Weight (mg.)	Dry Weight per sq. cm.
Full Light	C*	C*			
Undefoliated	33.6 (13%)	0.82 (15%)	26.2	65.3	2.50
Defoliated at 8 cm.	26.2 (19%)	0.55 (14%)	13.7	33.3	2.44
,, ,, 4 cm.	23.2 (19%)	0.50 (12%)	11.0	24.4	2.21
,, ,, 2 cm.	17.1 (15%)	0.39 (19%)	6.3	12.2	1.93
Undefoliated—Series B	34.9 (13%)	0.69 (14%)	22.9	55.6	2.43
Base Shaded					
Undefoliated	43.3 (19%)	0.51 (22%)	21.0	47.3	2.25
Defoliated at 8 cm.	31.8 (24%)	0.48 (25%)	14.5	26.8	1.85
,, ,, 4 cm.	30.5 (20%)	0.51 (19%)	14.8	29.9	2.02
,, ,, 2 cm.	23.7 (22%)	0.49 (15%)	11.0	18.4	1.67

*C co-efficient of variation.

From the dimensions of the 9th leaf on the primary tiller a more detailed comparison of treatment effects can be made (Table 6). The leaf blades on undefoliated plants were longer where base shaded, but narrower and of lower weight per sq. cm., and hence of less area and total weight.

With plants in full light, the four defoliations to 2 cm. reduced length, width, and weight per sq. cm. so much that the blade was only one fifth the weight of that on undefoliated plants.

Growth of a Single Tiller

The quantity of tissue formed on a vegetative tiller each day is the product of the mean width and thickness of the leaves being formed, and their increase in length during the day. If a short-rotation ryegrass plant is growing vigorously, two, or occasionally three, leaves may be elongating simultaneously. Thus, although the increment in total length of leaf on a tiller was as high as 5 or 6 cm. per day on undefoliated plants in full light, the increase in length of an individual leaf was never more than 2 to 3 cm. per day.

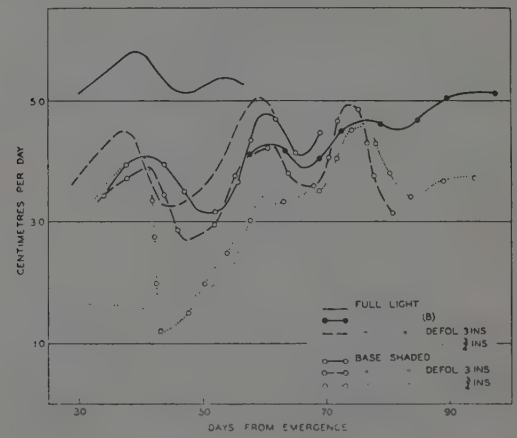

Fig. 6.—Total daily leaf elongation on primary tiller. This includes elongation of all growing leaves.

In Fig. 6 two cycles of 5-point smoothing were used to eliminate short-term fluctuations in measured leaf elongation. It is clear that all treatments follow the same peaks and troughs, due to changes in weather conditions during the trial.

From a comparison of the general levels for leaf elongation (Fig. 6) and rate of tissue formation (Fig. 7) it can be seen that:

1. Although there were initially wide differences in the amount of leaf elongation each day among treatments, these diminished and in large measure disappeared by the middle of May. However, there remained large differences in weight of tissue being formed, largely owing to differences in the width of the leaves.

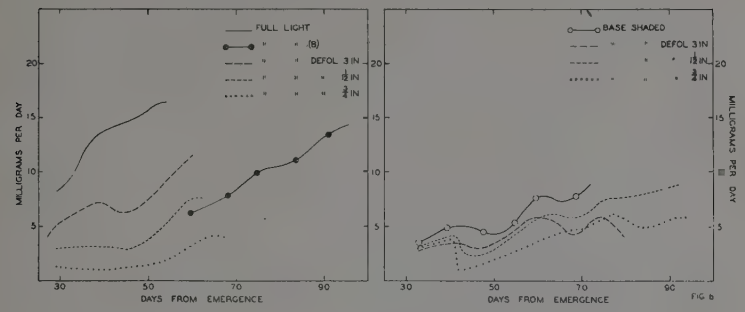

Fig. 7.—Dry weight of tissue formed each day by the primary tiller.

2. Prolonged reduction in weight of tissue formed each day resulted from severe defoliation of plants in full light. On day 66, i.e., 25 days after the last defoliation, the primary tiller of plants defoliated four times to 2 cm. formed only 2 mg. of tissue, but on plants undefoliated it formed 17 mg.

3. Base shading reduced rate of tissue formation of undefoliated plants to less than 50% of that of plants grown in full light.

4. For the base-shaded treatments, the relative reduction in rate of tissue formation resulting from defoliation was less than it was for the groups of plants continually in full light. This was largely because leaf width was relatively little affected by severity of defoliation, where plants were base-shaded.

5. The group of plants grown in full light without defoliation, but sown a month later (Series B), gave rates of leaf elongation comparable with the earlier sown group but at equivalent stages of development formed tissue more slowly. This was due to a decrease in width of comparable leaves, presumably arising from current or previous differences in environmental conditions.

Population Variability

In the first experiment, base shading was adjusted to give each plant 30% light, i.e., the shades were not set to the same level for the whole group. This was needed for fair comparison between the different methods of shading. In the second experiment, all treatments were applied uniformly, irrespective of habit of growth of the plant, a procedure comparable with conditions met by a population of plants in a pasture. In addition, only one plant, instead of three, was put in each pot, to eliminate possible interaction between plants.

Observations in both sets of experiments suggested that certain treatments increased variability among plants. For instance, in the first experiment, where a group of plants had been shaded and then

brought into full light, some formed large lush tillers characteristic of Italian ryegrass, and others formed many small tillers.

Visible differences in amount of variability within treatment groups appeared early. Observation suggested that whether such variability became greater or less as the trial progressed depended again on the particular treatment.

Where plants were given a uniform level of base shading, the co-efficients of variation for total shoot weight were higher for base-shaded groups than for the groups in full light. They ranged from 17% and 18% for undefoliated plants in full light to 61% and 84% for the groups base-shaded for the longest period during the experiment (Table 7). In this experiment this was due to greater variation, not in number of tillers per plant, but in weight per tiller and hence in the weight of individual leaves.

TABLE 7. CO-EFFICIENTS OF VARIATION FOR SHOOT WEIGHT, TILLER NUMBER, TILLER WEIGHT, AND GREEN WEIGHT OF BLADE ON THE PRIMARY TILLER

Treatment	Shoot Weight	Tiller Number	Tiller Weight	Green Weight of Leaf Blade
Full Light				
Undefoliated	17%	26%	22%	28%
Defoliated at 8 cm.	26%	31%	26%	30%
„ „ 4 cm.	27%	29%	18%	32%
„ „ 2 cm.	31%	33%	31%	30%
Undefoliated—Series B	18%	30%	31%	26%
Base Shaded				
Undefoliated	61%	30%	47%	58%
Defoliated at 8 cm.	84%	37%	64%	52%
„ „ 4 cm.	45%	22%	38%	39%
„ „ 2 cm.	43%	31%	43%	42%

Two factors tend to produce an inverse relationship between tiller weight and tiller number per plant. Firstly, in any population where there is a continuous growth of each unit—in this case the tiller—the higher the rate of increase in numbers, the lower will be the average weight per unit. Secondly, each plant tends also to grow as a unit, in which a fixed quantity of energy metabolite from photosynthesis can be distributed to form either few large tillers or many small ones.

For the two groups of plants grown undefoliated in full light, this inverse relationship between tiller number and tiller weight is present (Fig. 8). However, where the plants were defoliated to 2 or 4 cm., variation in number of tillers per plant was accompanied by relatively little change in weight per tiller. Some plants had continued to tiller rapidly but with others the check to growth from defoliation caused them to form, not only fewer tillers, but also relatively small ones. Where

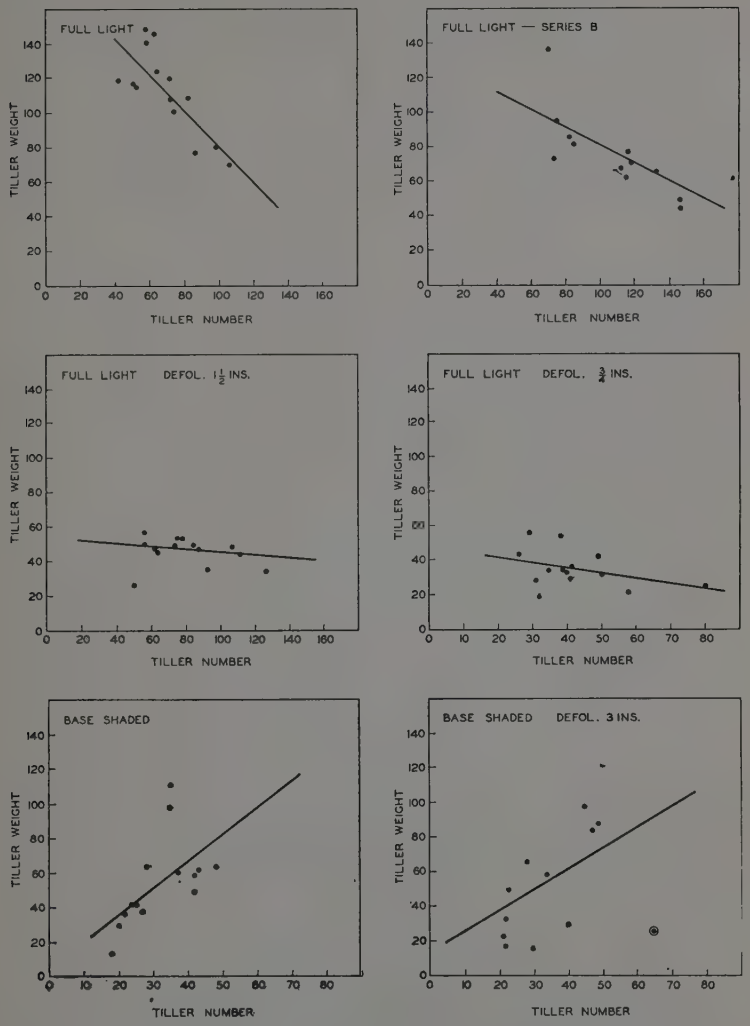

Fig. 8.—The influence of defoliation and base shading on the relationship between tiller number and tiller weight of individual plants. In the four groups in full light, tiller numbers from an observation before final harvest are used. This raises apparent tiller weights but does not affect the relationships.

plants were base-shaded during most of their growth, the original relationship was reversed. Tillers were largest on plants which had most of them.

Average tiller weight is largely a measure of average leaf size. Where large leaves can reach the light, the plant can receive a larger quantity

of energy metabolite to form more tillers and more leaves, which in turn reach up to the light. If those large leaves are not formed, tillering is discouraged.

This does not occur automatically. In the group of plants base-shaded and defoliated to 8 cm., one plant, marked with a circle in Fig. 8, formed the largest number of tillers in the group despite having short leaves. If this plant is included, there is not a significant regression of tiller number on tiller weight but if it is excluded the regression is highly significant.

Discussion

The results may be very briefly summarized as follows. With plants grown in full light, repeated defoliation checked tillering a little but drastically reduced quantity of tissue formed by individual tillers. This was largely due to a reduction in the size of the leaves formed. The effect persisted for several weeks after defoliation ceased and was proportional to the intensity of defoliation. Plants defoliated severely and repeatedly assumed a habit of growth resembling that of perennial ryegrass and this persisted for several weeks beyond the actual period of close defoliation.

Base shading reduced both the tillering and rate of tissue formation on a tiller. When base-shaded plants were defoliated and then placed in full light for a period, tillering was increased and the reduction in tissue formation by an individual tiller was relatively small. In the field, absence of either defoliation or shading would occur only where a plant is growing as an isolated tuft.

Conclusions drawn from the results are applicable only to cooler periods of the year when light and temperature conditions resemble those in the present trials. The pattern of response to the various treatments may be considerably different under hot summer conditions.

For comparison with pasture conditions, four defoliations at 6-day intervals should resemble a period of continuous grazing. Where defoliation was close, to 2 cm. height, there was only 25% as much tissue formed by an individual tiller as on plants defoliated to 8 cm. In turn, tillers defoliated to 8 cm. formed less than 60% as much tissue as undefoliated tillers.

However, in cool conditions there could be continued rapid formation of fresh tillers, despite close defoliation. Although the tillers formed would be small, the type observed were sturdy and quickly formed their own root system. Thus, satisfactory production from an area of pasture could be obtained from the growth of large numbers of small vigorous tillers.

In plants that have been base-shaded, i.e., given growth conditions similar to those in a long pasture, a single defoliation resulted in a relatively small reduction in quantity of tissue formed on an established tiller. It cannot be taken that growth of pasture will always be slowed by a lenient grazing, for a proportion of the existing tillers may be destroyed by trampling or pulling. Provided temperature and soil-surface conditions are satisfactory, these can rapidly be replaced, but the new tillers have initially smaller leaves than the mature ones from which they grow. The closer the defoliation the more pronounced this becomes.

This loss of large tillers and their replacement by initially small ones may at times be as much responsible for the slowing down of pasture growth resulting from defoliation, as reduction in growth from a defoliated tiller.

Although the initial increase in tiller number on base-shaded plants cut at 8 cm. was little greater than on plants cut at 4 or 2 cm., the appearance of the new tillers was different. In the former case robust, relatively broad-leaved tillers, generally similar in appearance to those appearing on plants in full light, grew up between the sheaths of older leaves. With closer defoliation a few such tillers, which had probably already been initiated at defoliation, were followed by numbers of slender, narrow-leaved tillers often emerging through the leaf sheaths. These probably arose from buds that had been inhibited to some extent. They would be very susceptible to damage by stock trampling.

For the undefoliated base-shaded group, the appearance of numerous slender tillers was responsible for the rapid rise in numbers at the end of the treatment period. With the continued growth of longer leaves, an increasing proportion of the photosynthetic tissue of these plants was above the shades. Presumably, metabolic status was eventually raised to a level sufficient for the initiation of growth from a number of axillary buds. The tillers formed were of a whitish, delicate appearance similar to young tillers seen in a long pasture. Their eventual survival in a sward would depend largely on a continuation of favourable growth conditions. On the one hand, they have to elongate considerably before receiving sufficient light to become independent of energy metabolite from the parent tiller, and, on the other hand, they are so delicate as to be very susceptible to sudden desiccation or heat should the pasture be grazed or mown.

Where the plants were base-shaded and defoliated to 8 cm., or where base-shaded continously, there was a large increase in the variation in the shoot weight of the plants. A reduction in shoot weight was accompanied by a reduction in mean tiller weight and hence in size of individual leaves. The plants in the population that could form large leaves, and hence get more light, would root firmly, be better able to stand the trampling and pulling of grazing, and be able to make rapid regrowth. The plants forming smaller leaves and hence more heavily shaded would form fewer tillers and a weaker root system, and would make slower regrowth after defoliation.

This implies that if a short-rotation ryegrass pasture is consistently allowed to grow long, shading competition between plants may result in death of many. There would be a thinning out of the pasture and the development of the sparse tufty appearance often seen in dairy-farm pastures sown with this type of ryegrass.

The appearance of increased variability in a relatively uniform population when transferred to another environment has been noted particularly for flowering characteristics[2] and when plants are transferred from one country to another[9]. Selection of types for a pasture strain, such as short-rotation ryegrass, has been based on characters expressed by spaced plants, intermittently defoliated, grown in various districts. Consequently, the plants selected can be expected to give most uniform results when grown in pastures in which the micro-environment around the plants is similar to the original selection conditions.

Where plants of this or other strains are grown in types of pasture in which essential features of the micro-environment are very different from the selection environment, an increase in variability may occur.

Acknowledgements

The assistance of Mrs. P. D. Fejer in carrying out the experiment and Mr. F. Tindall in draughting the diagrams is gratefully acknowledged.

These experiments arose from suggestions put forward by Mr. P. D. Sears.

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RAGWORT SEED-FLY ESTABLISHMENT IN NEW ZEALAND

By J. M. Kelsey, Entomological Research Station, Department of Scientific and Industrial Research, Ashburton

(Received for publication, 29 December 1954)

Summary

The establishment of the seed-fly (*Hylemyia seneciella* (Meade)) on its host plant *Senecio jacobaea* L. is traced over a period of 17 years. Within 13 years the fly increased in numbers from the 36 liberated to over 4,500 millions, and at the end of 17 years was present in all ragwort stands in an area approximately 10 square miles round the liberation site.

Laboratory examination of "early" and "main" crops of flower heads showed that slightly over 98% of them were infested, but that the "late" crop flowers were not infested.

Tests showed that though some seeds were usually left in flower heads after larval activity ceased, these seeds did not germinate; this could be due to tissue collapse of seeds immature at time of infestation, or to the influence of a mould always present in infested flower heads.

Introduction

This paper is a record of establishment of the ragwort seed-fly (*Hylemyia seneciella* (Meade)) in one locality in New Zealand, and shows how an insect sometimes may be successfully established from unpromising material.

Ragwort (*Senecio jacobaea* L.) in the area in question has each year three fairly distinct flower crops, which can be called "early", "main", and "late". The first and last of these are separated in time by approximately eight weeks, and the late crop is made up mainly of flowers on stunted plants, or those injured by grazing stock, wind, or other agencies. The main crop, as its name suggests, includes most of the flowers—about 75% of the total crop—while early and late crops divide the remainder fairly evenly.

The average number of flowers on 50 well established ragwort plants was 1,147 (range 674-1,708), the average number of seeds per capitulum was 66 (range 49-81), and average germination was 70% (range 58-96%).

The seed-fly oviposits in flower heads in which the outer ring of florets is opening, and, therefore, before seeds are mature. The larva makes its way to the base of the flower head and commences to feed on developing seeds, the de-seeded flower being forced out beyond the surface of other florets to project in a manner characteristic of infestation. Each larva attacks only one capitulum and, when fully fed, it bores through the base of the flower head and drops to the ground into which it tunnels to pupate. A larva does not, however, usually eat all seeds in a capitulum, the average number left being 12 (range 0-22). At this stage, infested flower heads usually have a greyish-black appearance due to presence of a mould, the growth of which is encouraged by larval excretions.

Liberation and Establishment

The ragwort seed-fly was introduced from England by Dr. D. Miller, Cawthron Institute, Nelson: the flies in this particular instance being a few that emerged rather late in the ragwort flowering season. The total number available for liberation was 103, only 36 of which were alive when containers were opened at the liberation site. The latter was a valley completely enclosed by redwood and pine plantations, and a few horses and wild pigs were the only grazing animals that would possibly disturb the progress of fly establishment.

The 36 flies were liberated on 12 February 1937, and the area was not visited again till January of the following year. At this inspection it was found that from 50 to 60 plants, scattered over an area of not more than 100 yards square, were infested, but no accurate count was taken as it was considered wise to leave the area undisturbed.

During February 1950, a further inspection showed that the fly was well established throughout the main valley—an area approximately 2½ miles by ½ mile in extent—and had spread from ¼ to ½ a mile up side valleys and just over saddles into adjoining valleys. It had spread down the road access valley for 1½ miles and was present in small numbers at the railway at this point, but not beyond the rail. An attempt was made to assess the percentage of infested flower heads in the most heavily infested area—1 mile by ½ mile—in the main valley. All flowers in ten 10 ft. by 10 ft. squares approximately 8 ch. apart, were examined. The average number of plants per ten-foot square was 42 (range 34 to 86) and 91% of the early crop, and 42% of the main crop of flower heads were infested, giving an average infestation of 66%. None of the flower heads of the late crop was infested. Based on the average number of plants and flower heads, a 66% infestation results in 32,472 seed-fly larvae per square, or about 4,526 million in the most heavily infested area in the valley.

A third inspection was carried out on 23 January, 1954, by which date the fly had spread across the railway, down the main entrance valley for approximately 1½ miles, and was present in nearly 20% of early and 8% of main crop flowers on farms 3½ to 4 miles beyond the liberation site. The fly is now present in all ragwort stands in an area of approximately ten square miles. Field inspection showed that 75.78% of early, and 29.01% of main crop flowers were infested in the main valley: 60.5% of early and 39.35% of main crop in the next valley 2 miles from the liberation site: 77.1% of early and 71.5% of main crop beyond the railway, and 19.98% of early, and 7.9% of main crop flowers beyond the road forks 3½ to 4 miles from the liberation point. In all, 10,919 flower heads were examined in the field, and an additional 5,512 were inspected in the laboratory to check actual infestation against field observations. Laboratory results showed that the infestation of all early and main crops of flower heads was 98.05% even as far as 2½ miles from the point of liberation of the original 36 flies. This shows that the field estimate of infestation was on the conservative side.

Viability of Seeds Remaining in Infested Heads

Seeds remaining in infested flower heads after fully fed fly larvae had dropped to pupate were tested for germination in a constant temperature room run at 77° F. and a relative humidity of 32%. The result

was that not one of 2,500 (5 replicates of 500) seeds germinated. Germination in mature seeds from uninfested heads ranged from 58 to 96% with an average of just over 70%. It is considered that there may be three main causes for germination failure in seeds from infested heads: the first is that activities of fly larvae commence and terminate at a time when seeds are immature; the second, that larval activity could adversely affect pollination of flowers; and the third, that mould growth, primarily caused by presence of larval excrement, invades the seeds and prevents germination. The mould finally spreads over the whole flower head to give it a greyish-black appearance.

In an endeavour to discover whether or not the mould could prevent seed germination, the following tests were carried out. Mould-infected seed from infested flowers was washed in a weak (2%) copper sulphate solution, followed by further washing in water to remove the chemical, but the seed failed to germinate, and still produced mould growth, though not to the same extent as did unwashed seed. The same treatment did not materially reduce germination of seed from uninfested, mould-free flowers. Mould-infected seed from infested flower heads was shaken up with clean seed from uninfested heads, and a germination test carried out immediately, the test period being 28 days. Though most of the previously clean seed germinated, mould growth prevented post-germination growth. This indicates that the mould could cause germination failure if seed was infested for the relatively long period during which it occurs in the field, as hyphae can penetrate the seed. Quite apart from the mould effect, however, the seed left by larvae is usually collapsed or otherwise distorted, so it is possible that the first factor above is responsible for germination failure.

From the above it can be seen that, though seed-fly larvae may leave an average of 12 seeds per capitulum, their presence could actually result directly and indirectly in 100% destruction of seed in infested heads.

Plants in three random 10-ft. squares were counted, and though these average 34 (67, 20, 35) as against the average of 42 in 1950, it is considered that the samples taken were not sufficiently extensive to allow wholly satisfactory conclusions to be drawn. In this area the late flower crop in 1950, accounting for approximately 12.5% of the total flower heads, appeared at a time when there were no adult flies to carry on infestation, and if this late crop is of annual occurrence, there would be sufficient seed in that crop alone to re-seed the area. Nevertheless, the seed-fly does prevent germination of seed in 87.5% of the total flowers produced in this one liberation area, and when it is considered that the present infestation originated from 36 flies and has spread within 17 years into all ragwort areas in a block of 10 square miles, it is obvious that this insect is a promising one, and it is suggested that the above area could be utilized as a source of material for more widespread liberations.

ACKNOWLEDGEMENT

The writer is indebted to Mr. J. W. Cleland for assistance in the field when an assessment of infestation was being made.

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PLANT QUARANTINE

IV. LIST OF PLANT DISEASES AND PESTS INTERCEPTED IN NEW ZEALAND IN 1954

By H. Jacks, Plant Diseases Division, Department of Scientific and Industrial Research, Auckland

(Received for publication, 13 December 1954)

Introduction

In this list are recorded plant diseases and pests intercepted in 1954 on plants and plant products introduced into New Zealand. Specimens were submitted by Horticultural Inspectors of the Department of Agriculture and identified by specialist officers of the Plant Diseases Division. Specimens submitted but found to carry organisms which could not be identified for various reasons, e.g. because of damage, failure in culture or rearing tests, etc., are not listed. Diseases and pests not established in New Zealand are marked with an asterisk.

LIST OF PLANT DISEASES AND PESTS INTERCEPTED IN NEW ZEALAND IN 1954

Disease or Pest		No. of consignments	Host		Country of Origin	Discovered in
Common Name	Generic Name		Common Name	Generic Name		
Diseases						
Anthracnose	*Glomerella cingulata* (Stonemn.) Spauld & V. Schr.	1	Oranges	*Citrus sinensis* Osbeck	South Africa	Wellington
Die-back	*Melanconis alni* Tul.*	1	Nursery stock	*Alnus* sp.	England	Christchurch
Die-back	*Melanconis stilbostoma* Tul.*	1	Nursery stock	*Betula* sp.	England	Christchurch
Die-back	*Diaporthe leiphaemia* (Fr.) Sacc.*	1	Nursery stock	*Quercus* sp.	England	Christchurch
Leaf spot	*Asterina baileyi* B. & Br.	1	Nursery stock	*Hakea* sp.	Australia	Wellington
Rust	*Puccinia antirrhini* Diet. & Holw.	1	Antirrhinum seeds	*Antirrhinum majus* L.	England	Wellington
Rust	*Cumminsiella sanguinea* (Peck) Arthur*	1	Nursery stock	*Mahonia* sp.	England and Holland	New Plymouth
Rust	*Chrysomyxa rhododendri* (DC) de Bary	1	Rhododendron	*Rhododendron* sp.	England and Holland	New Plymouth
Pests						
Coffee-berry borer	*Stephanoderes hampei* Ferr.	1	Coffee beans	*Coffea arabica* L.	Uganda	Auckland
Copra bug	*Necrobia rufipes* de Geer	2	Coconut	*Cocos nucifera* L.	?	Wanganui
Cowpea weevil	*Bruchus* (*Callosobruchus*) *maculatus* Fabricius	1	Beans	*Phaseolus* sp.	U.S.A.	Auckland
Scale	*Icerya seychellarum* Westwood	1	Specimen		Nauru Is.	New Plymouth
White fly	*Pealius kelloggi* (Bemis)	1	Croton leaves	*Codiaeum* sp.	Fiji	Auckland

BORON DEFICIENCY SYMPTOMS IN RASPBERRIES

By R. J. Monk, Cawthron Institute, Nelson

(Received for publication, 13 January 1955)

Summary

Symptoms of boron deficiency were developed in raspberries grown in sand-culture. The symptoms confirm those previously associated with boron deficiency in the field.

Introduction

An ailment of raspberries known as "die-back" was identified in the Nelson district as a boron deficiency symptom[1]. As a check on this identification an attempt was made to induce symptoms by growing raspberries in sand under conditions of low supply of boron.

Experimental

Attempts to establish raspberries in a fine quartz sand in a glasshouse failed. Plants made a good initial growth but subsequently collapsed and died. Examination of the plants showed that no rooting system had developed. The experiments described here were made in the open using a coarse granite sand.

A series of twenty-one glazed and waxed crocks, filled with granite sand treated with mild acid to remove nutrients, was planted with rooted shoots of the Red Antwerp variety of raspberry. The sand had a hot-water-soluble boron content of 0.12 p.p.m. Application of the major nutrients and of purified water, and the general cultivation of the plants, were identical for all pots. The only difference in treatment was in the use of the minor elements boron, zinc, copper, and manganese. Six different treatments for minor elements were adopted, namely:

(1) All the minor elements; (2) all except boron; (3) all except zinc; (4) all except copper; (5) all except manganese; and (6) no minor elements at all. Where minor elements were added this was done by the use of dilute solutions of the elements concerned. In the case of boron, 1 ml. of a solution containing 0.5 g. of boron per litre was added at intervals, a total of 9.5 mg. of boron being applied in two seasons.

Plants that did not receive zinc, copper, or manganese did not differ in appearance from those that received all the minor elements, and appeared to grow normally and healthily. Abnormal growth appeared only on plants that received the minor elements except boron, and on those that received no minor elements at all. This suggests that the abnormalities developed in these plants were due to deficiency of boron and that, owing to the mild acid treatment given to the sand, sufficient of the metals zinc, copper, and manganese was left to permit normal growth as far as those elements were concerned.

In the 1952 53 season, plants were established in sixteen of the twenty-one pots, the plants in the remaining five pots failing to establish a rooting system. Several replantings were made in all but six of the pots so that the plants that were finally established were not all planted at the same time, some ten weeks elapsing from the initial planting until the final replant was made.

Of the six plants that took root after the initial planting, four received boron and grew normally. Of the remaining two plants, one received all the minor elements except boron, and the other received no minor elements at all. Both of these plants showed abnormal growth and, together with one receiving all minor elements, are shown in Fig. 1. Distortion of the leaves in "C", and especially in pot "—B", is very marked. The boron contents of the leaves from these plants, expressed on the dry basis, were:

Plant T (all minor elements)	22.3 p.p.m.
Plant C (no minor elements)	6.0 p.p.m.
Plant —B (all minor elements except boron)	4.3 p.p.m.

In the 1953–54 season, plants were established in twenty-one pots. In every case where boron was added growth was normal while in every pot where no boron was added growth was abnormal. In the six pots mentioned above, which had grown the full 1952–53 season, growth was more vigorous than in the remaining pots but, on the other hand, the symptoms were more severe in the older plants. The symptoms

Fig. 1.—Boron deficiency symptoms in raspberries 1952–53 season. Healthy plant on left.

appeared first on plants established at the beginning of the 1952–53 season, then, about two weeks later, on plants established later in the 1952–53 season, and finally on plants established in the 1953 54 season. In the latter, the symptoms appeared some six weeks after they occurred on the oldest plants. Fig. 2, photographed in the 1953–54 season, shows the same pots as appear in Fig. 1. The malformed leaves of pots "C" and "—B" are easily seen.

In the 1953–54 season, leaf samples from each minor element treatment were analysed for boron content with the following results:

Treatment	p.p.m. B on dry basis
No minor elements (C)	8.2
Boron absent (−B)	8.3
Copper absent	34.5
Zinc absent	33.1
Manganese absent	33.3
All minor elements present (T)	34.6

It would appear therefore that the abnormal growth in two seasons in pots that did not receive boron is due to a deficiency of this element in those plants. Though these plants have canes much smaller in size and number than field plants, the symptoms in them are recognizably similar to those identified as boron deficiency in the larger bushes in the field.

Fig. 2.—Same plants as in Fig. 1: 1953–54 season.

The most characteristic leaf symptom of boron deficiency in raspberries is the "feathery" appearance where the leaves are elongated, thin, and deeply indented. This symptom occurred very seldom in the field on young canes of the current season's growth, but in the pots where comparatively little growth from the previous season was present, it appeared markedly on the leaves of young canes. On the other hand, the field symptoms that were most marked on the "old" growth, namely the delay in buds coming to leaf or even the complete failure of the bud to burst, were not so noticeable in the pot plants. However, the symptoms did occur, as did failure of fruit to set in those buds that flowered. In less severely affected canes, the leaves had a crinkled uneven surface with ill-defined edge serration and a down-curling similar to that recorded in the field. This symptom and also the "feathery" leaf symptom are well illustrated in Fig. 3. In the pot plants showing deficiency symptoms

Fig. 3. The "feathery" symptom and the crinkled uneven leaf. Healthy plant on left.

there also occurred secondary lateral growth, which did not occur in the boron-treated plants and was not recorded in the field symptoms. These secondary laterals in most cases showed the "feathery" leaf symptom.

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BOOK REVIEW

GENETIC HOMEOSTASIS

By I. MICHAEL LERNER

Messrs. Oliver & Boyd Ltd., Edinburgh. 12/6 net.

Genetic homeostasis is defined as the self-regulatory property of an interbreeding Mendelian population; it translates to the population level the well-recognized phenomenon of developmental (physiological) homeostasis in individuals, that is their capacity of adjustment to variable environmental conditions. Lerner propounds the theory that an obligate level of heterozygosity is the key to both phenomena; that, for adaptive characters, the heterozygous individual is better canalized or buffered (natural selection favouring the average genotype), with the corollary that "the basic requirement of a Mendelian population for successful existence is the maintenance of heterozygosity" (page 118), directed towards maximum average fitness. This acts at once as a stabilizing force, restricting rapid change of the population mean in either direction, and at the same time confers a long-term flexibility permitting evolutionary adaptation in the face of altered environments. In population genetic terms, "fitness" itself and adaptive characters in general exhibit overdominance while metric traits may still be considered as inherited under additively-acting polygenic systems. (The distinction between "metric" and "adaptive" traits seems open to question.) The result is that artificial selection, customarily for the extreme manifestation of a trait, is opposed by natural selection, favouring the average. The final point in the thesis, namely that polygenes affecting continously distributed traits are organized in blocks, is invoked to account for renewed responses to selection after a "plateau" period.

The major portion of the dissertation is devoted to description and consideration of available evidence, primarily from selection experiments with Drosophila, poultry, and mice, but also, far more than in any preceding study, from domestic animals. Several instances are cited, including some of the author's own poultry studies, where intensive artificial selection has failed temporarily to increase the value of the selected trait above a certain "plateau" despite apparently ample remaining genetic variability. Other evidence concerns the sporadic but ubiquitous occurrence of "phenotypic deviants" (postulated as due to individuals exceeding a certain threshold level of homozygosity), comparison of variability of homozygotes and heterozygotes (the apparent reduction in the latter case arising from their better buffering), inbreeding degeneration, balanced polymorphism, and observed superiority in fitness of phenotypic intermediates and generally of heterozygotes.

The formulation is necessarily largely inductive in the present state of knowledge of cytological and physiological genetics; the more deductive experimental validation remains to be undertaken. Undoubtedly the theories are in conformity with the facts as presented (the question of selection of data might perhaps be raised here) but in several instances they become purely speculative and the cogency of the author's arguments fails to dispel doubts that alternative explanations might not be equally appropriate.

As regards application, there seems little practical merit in the suggestion (page 100) that breeders' efforts should be directed to the production of superior populations rather than superior individuals. Excessive inbreeding is already avoided and cases where improvement of economically important traits has reached a plateau or is limited by diminished fitness would surely be exceptional. Certainly inclusion, in a selection index, of "fitness" would be desirable—but a measure of it is first needed! Generally the study appears more relevant to long-term trends (evolution) than to short-term (breeding).

The following specific comments may be made: Three entire sections purport to demonstrate that environmental variability in traits of adaptive significance is less among heterozygotes, the consequence of their better buffering properties. Following Gustafsson, the coefficients of variation are shown to be greater in inbred than in crossbred lines in the instances cited. Surely, however, the comparison should be of the absolute variability which, in general, is less in the more highly inbred group (for example, Tables 11 and 12), by no means substantiating the conclusion "that heterozygosity reduces variability around the

adaptive mean value of a character" (page 62). Only in the presence of pronounced heterotic effects is the relative variability less in the more heterozygous group. (One infers here that heterosis is only exhibited in "adaptive" traits.)

Although the author points out that one worker (Goldschmidt, page 73) confuses selection and inbreeding, their effects tend to be confounded in much of the other evidence cited, including that from the author's own experiments, for example, for increased shank length in chickens. It is not conclusively demonstrated that deceleration of gains already noted is not merely due to inbreeding *per se*. In this connexion, one significant fact emerging is the apparent bias in the standard method of adjusting variance (and heritability) estimates for degree of inbreeding; the actual homozygosity tends to be materially less than that computable from pedigrees.

A further point worthy of note is that the evidence on selection largely concerns characters not directly related to general fitness. The resulting antagonism between artificial and natural selection may not apply in practical improvement problems where, in general, the traits of economic importance tend to be associated with fitness. Similarly, considerable attention is devoted throughout, both empirically and theoretically, to characters simply inherited on the basis of one or two genes; caution is necessary in extrapolating to the more complex genetic models underlying continuous variation.

The book is well written, though the very comprehensiveness of the evidence adduced militates against easy reading. Few misprints were noted: On page 54, line 3, "heterozygotes" should be "homozygotes" and the converse on page 66, line 27; on page 79, paragraph 4, line 5, "negatively" should presumably be "positively"; and on page 115, paragraph 3, line 3, "inefficient" should surely be "efficient". The bibliography is good but no index is provided. It is a book for the genetic specialist rather than for the student or practical breeder, and its value lies perhaps as much in its review of pertinent data, scattered through a wide literature, as in the theory put forward. All in all it represents a useful and stimulating contribution to present-day genetics, reflecting a striking departure from certain widely-accepted earlier theories, and pointing to interesting future developments.

A. H. CARTER.

CORRIGENDUM

An amended map is enclosed, to replace map on page 338, Volume 36, A (December 1954).

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